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SOIL SCIENCE AND THE PRACTICE OF AGRICULTURE.

ANY general survey of the organizations conducting agricultural research will show to what extent their finance is derived from official sources. In this respect agriculture differs markedly from industry which has, to a very large extent, incorporated research departments within its organization. The explanation of this difference is that, while industry as a whole has realized that research is a profitable investment, agriculture has not. The agricultural community accepts the need for research only to the extent of raising an outcry at any proposal for discontinuance but is not prepared to find the money which would be required if all official aid were withdrawn. The reasons for this different attitude in the two communities is worth a moment's study; and if soil science is selected to illustrate the argument, it is because this science, in its bearing on agricultural practice, demonstrates the causes more clearly than any of the other sciences impinging on agriculture.

If science is to make that real appeal to the agricultural community which will assure adequate financial assistance, it must bring the broad conclusions of research into such close harmony with practice that the individuals composing that community cannot fail to realize the benefits conferred. It must help the individual to derive an advantage which he cannot overlook. What is an advantage of this nature? It is that, at little or no added expenditure, he reaps an appreciably enhanced yield of high quality produce. It will be sufficient here to limit the argument to the first of these, high yield. The farmer's objective is to realize the maximum yield of which his land is capable. To achieve this he must strive to bring the conditions of growth to the optimum for the crop. That optimum may be fairly well defined but, if it is to be attained, something more than a knowledge of the conditions which compose it, is required. The compass direction by which you will travel to reach a certain point will depend on your starting point and, in the same manner, the farmer must know his starting point if he is to arrive at his objective. In other words, according to the particular nature of that very variable medium with which he works, the soil, he will adopt to a greater or less extent a different cultural procedure. The greater his knowledge of the soil, the greater will be his chance of success. Since

the variability of the soil is such that field differs from field and even one part of a field from another, he is at once faced with a very local problem. It is this individuality of the problem presented to each farmer in the case of the soil that makes the consideration of soil science so pertinent to the present argument.

In recent years rapid strides have been made in the study of the soil. In his Presidential Address at the last meeting of the British Association, Professor Hendrick pointed out that "most of our scientific knowledge of the soil has been built up during the last century. This knowledge has been advancing ever since but with particular rapidity during the present century". That statement covers the whole field of soil science. The studies on which that science is based, are, broadly, dual; the more fundamental, covered by the term pure research, and the less fundamental, dealing with the application of discovered principles and termed applied research. The distinction is not sharply drawn and lies in the objective rather than in any specific character of the work itself; but they are interdependent, application following on discovery and discovery often following experience in application. If the science is to make its maximum appeal, such an appeal as will attract the necessary finance, these two branches must proceed in step; only so will the findings of pure research be immediately scrutinized for any possible application. That they are not in step, that application lags behind theory, is hardly open to question, as one example will indicate sufficiently.

Of all the institutions at which the study of the soil in its various aspects is conducted, it is Rothamsted which has led the way, particularly in the matter of fertilizers. As the result of these English investigations, if there be one point which stands out pre-eminently, it is that the soil is a very variable medium and that the character of the soil is the major factor in determining fertilizer requirement. Yet, in this same country, fertilizer catalogues are still being issued in which compound fertilizers are classified according to the crop grown. It is on such catalogues that the average English farmer purchases his fertilizers and it is no uncommon experience to find a farmer using the same fertilizer for light loam and heavy clay and irrespective of concurrent dressings of farm-yard manure. There is here clearly a lack of liaison between research and practice and, in consequence, the work of the research organizations not only in England but in many other countries, has failed to make that appeal to the agricultural community which finds its expression in the provision of adequate funds. In it, too, lies the basis of the charge that there is too much research, the answer to which charge is that there is too little use made of the results of research and that the best remedy is to bring practice up into line with research and not to limit research to the level of present practice. These considerations appear to lead to the conclusion that what is required from the research station is a greater attention to practice, but it is not a conclusion which will be supported by further argument.

The practical problems of the soil are, as has been noted, severely local, each field and even each part of a field offering its own particular problem. It may well be asked can any centralized research organization, whatever the finances at its disposal, be so equipped as to make an effective study of such very local problems? The answer is clearly that it cannot. Apart from the fact that each field must be considered in regard to siting facilities for drainage and so on, the various technical tests which would have to be applied to each case, involve a mass of tedious analytical work which render the suggestion impossible on the grounds of time and personnel. But the general absence of any agent in a position to make the necessary investigations has forced research organizations to attempt to fill the gap. It is a praiseworthy effort but it has led to unfortunate consequences, as any attempt to achieve the impossible is likely to lead; the lag noted in practice is taken as proof of the uneconomic value of research and research largely discredited. There is here a logical sequence which, unfortunately, has not received general recognition, particularly by those entrusted with the fortunes of research organizations. Admission of the difficulty is, it is true, implicit in such a statement as 'under the conditions of the experiment' such and such a result is obtained; but these conditions only hold for the particular area of the experiment and the results, therefore, may not apply to the next field. A more explicit admission is contained in the following extract from British Guiana*:—

> "It is unlikely that the small number of field experiments can do more than furnish pointers towards the optimum amounts (of fertilizers), such pointers serving as the basis for large scale experiments by the plantation managers themselves."

It is a very natural instinct, that of self preservation, which compels such organizations, having entered the practical field, to attempt to justify their existence by results, but they would be better advised to stimulate the development of intermediary agents, organized on a local basis, with which they could work in co-operation. That their stock would rise thereby and their position be established on a firmer basis, can hardly be doubted.

The advantage of such an intermediary agent may be illustrated by actual example. The sugar industries of both Java and Hawaii are conducted on progressive lines. Perhaps the most widely appreciated of the Java work is that concerned

Sugar Bulletin No. 5.

with the breeding of canes, a fact which is largely due to the world-wide spread of canes of the POJ series. But less well-known work on other lines has been carried out and contributed its quota to the steady increase in yield which is characteristic of the Java sugar crop. Notable in this work is an intensive study of the soils. Results of a similar nature have been obtained in Hawaii where the yield has been doubled in some ten years. For reasons into which it is unnecessary to enter here, the facts concerning Hawaii illustrate the present argument most clearly and will be considered.

The Hawaiian sugar industry is organized on a capitalistic basis. The individual plantations, the unit of production, are themselves progressive but they have, further, combined to form an Association, The Hawaiian Planters' Association, which, among other activities, finances and controls an experiment station. The staff of this station has, among other subjects, devoted much attention to the study of Hawaiian soils and, particularly, to the determination of the available plant food with especial reference to fertilizer practice. The practical problem to the solution of which this work is directed, is the economic use of fertilisers, the more effective use of these and, perhaps, a saving in the fertiliser bill. With the very variable nature of the soil, it is clear that a dressing which will ensure an adequate return on the poorest sections of the area, will entail excessive dressings on a large part of the area and a waste of fertilizer. The problem, thus, resolves into one of finding the ways and means of determining local variations of the soil, not only from field to field but from one part of the field to another. The accepted technique for such determinations was, obviously, too tedious to supply the required data and the search for alternative methods passed in review field experimentation, Mitscherlich pot tests and the *Aspergillus* method. To these has now been added a series of R.C.M. (Rapid Chemical Methods) tests. They cover available and total nitrogen, readily soluble phosphate, phosphate fixation, readily available potash, calcium and soil reaction. These tests have been standardized so that they may be conducted by any staff trained in routine method, and detailed instructions have recently been issued. The methods are so rapid that analyses which would take months by the standard technique, can now be done in the course of a few days. By them sectional field analyses become a practical proposition. It is not claimed that they are infallible, but it has been shown, by correlating the results with those obtained by other methods, that they offer a very real assistance in extending the information obtained from field and pot tests.

Arising out of this standardization of rapid methods, an organization has been built up under which each plantation conducts its own analyses while the experiment station supplies and guarantees the equipment and reagents (kits), conducts duplicate tests of a proportion of samples as a control, investigates any discrepancies which may arise, and keeps touch with the plantation organization by means of frequent visits. By this means, plantations are in a position to prepare maps and to use these maps to draw up fertilizer programmes. Differential fertilization has, in fact, become a practical proposition.

Characteristic of this technical organization in Hawaii is its finance and control by the industry itself. The practical aspect is kept rigidly in the foreground and it is primarily an agent for interpreting the results of research, departing only from practice to elucidate, by pure research, points which have arisen in practice. That it has 'delivered the goods' is proved by the fact that the industry has continued to provide the finance. Further, it may be noted that this organization alone could not have achieved its success. It has had the whole body of research throughout the world to draw on. The two organizations are, in fact, complementary and only by mutual interaction will research and practice be kept in step.

It is not without significance that, both in Java and in Hawaii, it is the sugar industry which has succeeded in applying the results of research to practice with such marked results. It may be that the dual nature of the sugar industry, with manufacture conducted in a factory under rigid technical control, has created a familiarity with technical method which has facilitated a collateral control in the field. That, however, is inadequate to explain the movement fully. In the early days the promoters must have had much faith, for results are not immediate. The real explanation appears to be that the sugar industries of these islands are run on a capitalistic basis with its accompanying advantage of flexibility of finance permitting the appropriation of funds for what must, at the time, have appeared to be a somewhat speculative venture.

The conclusion can hardly be avoided that it is the organization of agriculture on a basis of small units which accounts for the general failure to apply the results of research to practice and the consequent failure of research organizations to secure a greater part of their finance from the industry itself. It is true of England, where the individualist farmer predominates; it is even truer of those tropical countries where a peasant system predominates. An agricultural department in such a country has very valuable work to do in conducting soil surveys, especially if the country is undeveloped. Such surveys are of use in helping to determine the best areas for settlement and so on; much loss and disappointment would have been avoided in the past by such information in preventing the development of areas found subsequently to be unfitted for the purpose. But it is inconceivable that any department could conduct that detailed work which will alone cause the fruits of research to

ripen into practice. The problem, in such cases, is the grouping of the peasants under some form of control which will give that flexibility of finance which permits allocation of funds for a venture speculative to the extent of doubt as to the when or the where of the return. Of the two methods of aggregation of peasant units, co-operation and corporation, the former, from its very nature, cannot supply the required conditions. A degree of control is required which union of similar units can never yield. This being so, it is unfortunate that corporations are generally held to be in opposition to the accepted policy for the evolution of native populations. It is unfortunate because, as long as the view persists, real progress of native peoples will be delayed. It would unwarrantably extend the length of this article to argue the point here ; it has already been dealt with elsewhere.

H. M. Leake.

A NOTE ON THE METHOD FOR EMASCULATING SUGAR-CANE FLOWERS BY MEANS OF AN ASPIRATOR.

By A. Glendon Hill,
Sugar-cane Research Station, Mauritius.

The emasculation of sugar-cane flowers, in sufficiently large numbers, has always presented an extremely difficult problem in cane-breeding so that the breeder normally avoids the issue by using only male-sterile, or partly male-sterile, inflorescences as female parents when making his crosses. This method has the disadvantage of limiting one's crossing material to a very large extent so that if a simple and practical method of emasculation were available it would increase the possible parental combinations considerably and simplify genetical studies, where undertaken. Such a method now seems to be available, as an adaptation by the writer of a clover emasculator used in the U.S.A.* has given promise of being of real practical value to cane-breeders. The apparatus used consisted of a small drawn glass jet connected by a convenient length of india rubber pressure-tubing to the intake of a car wind-shield wiper, a vacuum flask being interposed in the pipe-line to equalise suction and to trap the anthers and pollen drawn in. To work the apparatus the car was parked, with engine running, as near as possible to the arrowing canes, the inflorescence to be emasculated being gently bent down until within convenient reach of the operator, when it was made fast to a stake in the ground. Only a small portion of each inflorescence can be emasculated on any one day, of course, as the florets open over a period of a week or more, beginning at the top of the inflorescence. After some experience with the apparatus it was found that the jet size and the rate of suction could be adjusted so as to just break the anther filaments and remove the anthers cleanly without damaging or removing too many stigmas at the same time. (*See* Fig. facing page 141.)

Emasculation can be carried out with considerable speed by simply running the glass jet along each flowering branch of the inflorescence, beginning near the rachis and working outwards.

* D. A. Savage, *Journ., Amer. Soc. of Agron.*, Vol. XXVII, No. 9, Sept. 1935.

THE CACAO INDUSTRY OF TRINIDAD.—*Continued.*

SOME ECONOMIC ASPECTS.

Series II.—A financial survey of estates during the seven years 1923-4 to 1929-30.

By C. Y. Shephard.

PART V.—COMPARISON OF VARIOUS GROUPS OF ESTATES.

SECTION (*d*).—COMPARISON OF ESTATES GROUPED ACCORDING TO AGE OF CACAO CULTIVATION (*See* Table IX and Figs. XXXVIII-XLIII).

Profits (*See* Figs. XLII and XLIII).

An examination of estates arranged in five age classes, ranging from less than 25 years to 85 or more years old, shows that the youngest estates are far more profitable than any other group, and that each increase in age is accompanied by a decrease in profits. The youngest class of estates earned profits of $24.60 (£5 2*s.* 6*d.*) per acre from cacao, or nearly twice as much as any other class. The 35-year old estates rank second in profits with $12.77 (£2 13*s.* 2½*d.*) per acre, the 55-year old estates are third with $11.91 (£2 9*s.* 7½*d.*), the 75-year old estates fourth with $10.60 (£2 4*s.* 2*d.*), and the oldest estates last with $9.52 (£1 19*s.* 8*d.*) per acre.

Yields (Fig. XLI).

The outstanding success of the youngest estates is due to the fact that they obtained the exceptionally high yields, judged by Trinidad standards, of 366 lb. per acre (8.22 bags per 1,000 pickets). There is very little difference in yield between the four older classes. The oldest two groups are actually second with identically the same yield of 269 lb. per acre. The 35-year old group is fourth with 257 lb. per acre (5.75 bags per 1000 pickets), and the 55-year old group last with 249 lb. per acre (5.52 bags per 1,000 pickets). Thus, there is a range in yield of only 20 lb. per acre between estates varying in age from 25 years to 85 or more years. These small differences in yield are not related to the differences of profit between the age groups. It should be noted that although the estates are typical of their present respective ages they are

COMPARISON OF TRINIDAD CACAO ESTATES GROUPED ACCORDING TO AGE OF CULTIVATION, 1926-7 TO 1928-9

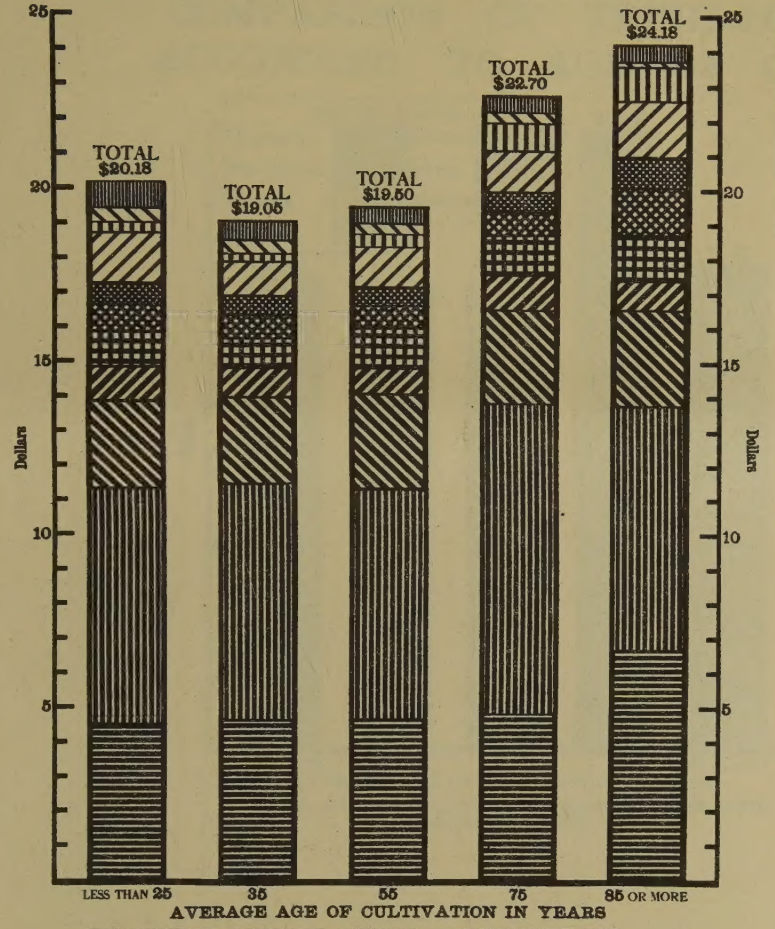
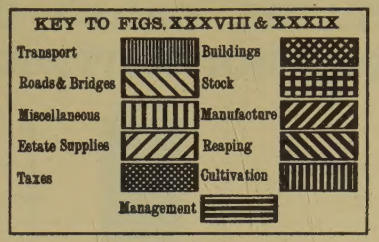


FIG. XXXVIII. AVERAGE ANNUAL EXPENDITURE PER ACRE



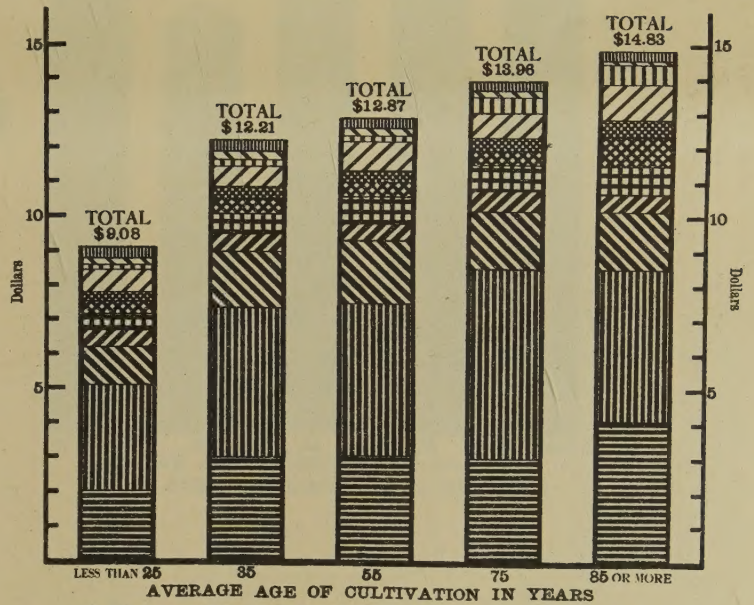


FIG. XXXIX. COST OF PRODUCTION PER BAG (165 lb.) OF CACAO

COMPARISON OF TRINIDAD CACAO ESTATES GROUPED ACCORDING TO AGE OF CULTIVATION, 1926-7 TO 1928-9

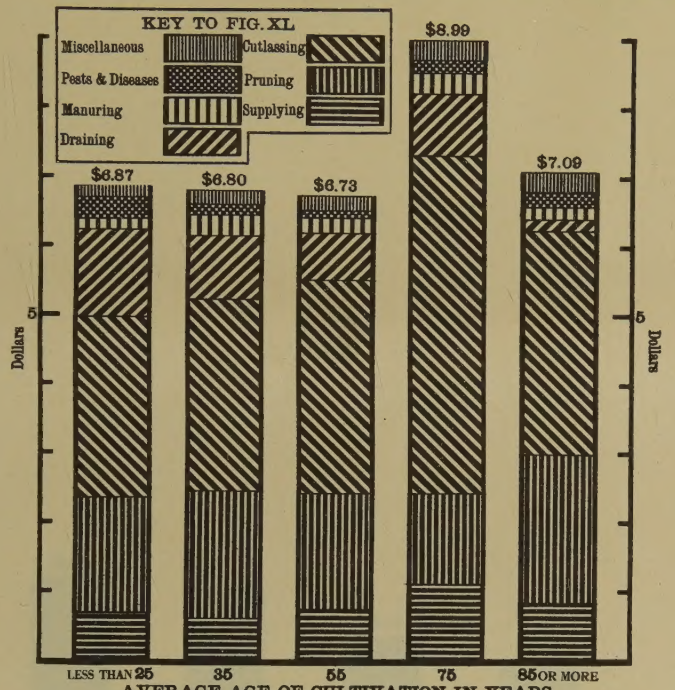


FIG. XL. AVERAGE ANNUAL EXPENDITURE PER ACRE ON CULTIVATION

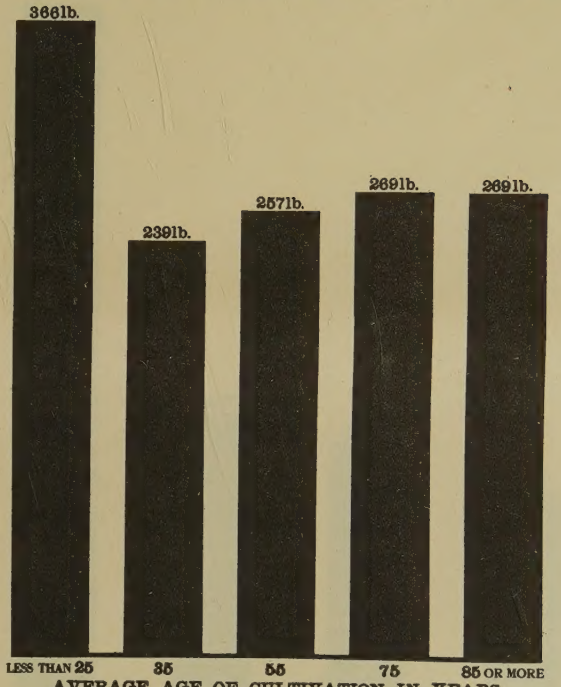


FIG. XLI. AVERAGE ANNUAL YIELD PER ACRE

not truly representative of all estates planted from 35 or more years ago. The yields of many estates fell, in the course of time, to such low and unprofitable levels that the cultivation was abandoned and replanted in other crops. If these estates had remained in cacao the yields of each successive age group would probably show a continuous decline. Importance should not be attached, therefore, to the fact that estates 65 or more years old yield slightly more than those aged 25 to 65 years.

Cultivation and Yields (*See* Figs. XL and XLI).

There is no relation between the differences in expenditure on cultivation and the yields of the various age classes. The 75-year old estates spend $8.99 (£1 17*s.* 5½*d.*) per acre on cultivation, which is appreciably more than that spent by any other class, but their yields are the same as the oldest estates, which spend $7.09 (£1 9*s.* 6½*d.*) per acre, and considerably less than the youngest estates which spend $6.87 (£1 8*s.* 7½*d.*) per acre. Apart from the 75-year old estates, there is a range of only 36 cents (1*s.* 6*d.*) per acre in the amounts spent on cultivation, but a difference of 117 lb. in yields. There is marked variation between groups of estates in the expenditure on individual operations.

Total Expenditure (*See* Fig. XXXVIII).

The largest total expenditure per acre was incurred by the oldest class, and with each younger age class there is a continuous reduction, with the exception of the youngest class which spends a little more than the next two age classes. The expenditure of $6.67 (£1 7*s.* 9½*d.*) per acre on management and supervision by the oldest group is notably high compared with $4.45 (18*s.* 6½*d.*) to $4.84 (£1 0*s.* 2*d.*) spent by the remaining groups. The expenditure of $1.42 (5*s.* 11*d.*) per acre on buildings by the oldest estates is also unusually high. There is a tendency for each increase in age to require a greater expenditure on the maintenance of equipment. The failure of the youngest estates to conform to the general tendency of decreasing total expenditure may be accounted for by the handling of larger crops, and the fact that some were still undergoing development.

Costs of Production (*See* Fig. XL).

The cost of production rises with the age of the cultivation. There is a large margin between the youngest and the next class. The former produces at the low cost of $8.96 (£1 17*s.* 4*d.*) per bag, and the latter at $11.87 (£2 9*s.* 5½*d.*), a difference of $2.91 (12*s.* 1½*d.*) per bag. In the other groups the costs of production rise by about $1 (4*s.* 2*d.*) per bag to $14.52 (£3 0*s.* 6*d.*) on the oldest estates.

Subsidiary Crops (Items 23, 32 and 33, Table IX).

The youngest estates derive the least revenue from intercultivated crops, but spend more than twice as much as any other group on separate subsidiary crops. All except the oldest two classes secured a small profit from crops other than cacao.

Mortgages (Item 39, Table IX).

Each increase in age from the youngest group to that 75 years old is accompanied by a rapid decrease in the amounts paid in interest on mortgages. The youngest estates pay an average of $3.19 (13*s.* 3½*d.*) per acre, and the 75-year old estates only 45 cents (1*s.* 10½*d.*) This trend may be explained by the ability of the young estates to maintain the payment of interest, and their shorter opportunity for liquidating indebtedness. The oldest estates, however, pay $1.69 (7*s.* 0½*d.*) in interest charges. They consist, for the most part, of estates which were at one time exceptionally profitable, and, despite their decline in efficiency, they have been able to continue the payment of interest.

Soil Type and Age of Cultivation.

Estates less than 25 years old therefore stand out as the most profitable, but within this and every other class there is an appreciable range in the yields, costs of production, and profits of individual estates. One estate, with cultivation averaging 60 years of age, earned profits practically twice as large as the average for the youngest estates. This estate is situated on soil which has long been recognised as of exceptional fertility. It is impossible to group estates according to soil because the distribution of the types is unknown. Moreover, most estates and many fields contain more than one soil type. Each estate is composed of fields which may vary appreciably in age, and only in a few instances are records of field yields available. It was therefore decided to investigate the influence of soil type and age of cultivation on yields and profits by examining more closely fields of different ages on the same soil type, and fields of the same age on different soil types. The results are presented in Series III.

Summary.

Estates with cultivation averaging less than 25 years of age obtained profits nearly twice as large per acre as any older group. Each increase in the age of the cultivation is accompanied by a decline in profits. Yields of cacao per acre are outstandingly good on the youngest estates, but show little variation between the older groups. There is no relation between the differences in expenditure and the yields of the various age groups. The total expenditure per acre increases with age in the four groups 25 or more years old. Costs of production are exceptionally low on the youngest estates, and rise with the age of the cultivation. The youngest estates derive the least revenue from intercultivated crops, but the most from other subsidiary crops. The youngest estates are the most heavily mortgaged, and there is a tendency for each succeeding age group to show smaller and smaller encumbrances. In general, then, the youngest estates are by far the most efficient, but it may be noted that one estate, with cultivation averaging 60 years of age, earned profits nearly twice as large as the average shown by the youngest estates. This estate is situated on soil recognised as exceptionally fertile, and it was therefore decided to examine individual fields of different ages on the same soil, and of the same age on different soil types, to ascertain the influence of age of cultivation and soil type on yields and profits.

Table IX.—ANALYSIS OF THE EXPENDITURE, REVENUE, &c., OF 162 TRINIDAD CACAO ESTATES GROUPED ACCORDING TO **AGE OF CULTIVATION** FOR THE THREE FINANCIAL YEARS 1926-7 TO 1928-9.

No.	Item Description.	Expenditure Per Acre of Cacao. Age of Group in Years. Under 25	35	55	75	85 or more.	Cost Per Bag (165 lb.) of Cacao. Age of Group in Years. Under 25	35	55	75	85 or more.	Item No.
		$ c.	$ c.	$ c.	$ c.	$ c.	$ c.	$ c.	$ c.	$ c.	$ c.	
1	Management and Supervision	4.45	4.65	4.65	4.84	6.67	2.00	2.98	3.06	2.98	4.09	1
	Cultivation:											
2	"Supplying" Cacao Trees	.69	.61	.73	1.11	.84	.31	.39	.48	.68	.52	2
3	Trimming and Pruning Trees	1.66	1.84	1.69	2.31	2.14	.74	1.18	1.12	1.42	1.31	3
4	Cutlassing and Weeding ...	2.62	2.78	3.10	3.90	3.25	1.17	1.78	2.05	2.40	1.99	4
5	Draining and Roundridging	1.26	.92	.67	.90	.18	.57	.59	.44	.56	.11	5
6	Applying Manure ...	.15	.30	.23	.30	.17	.07	.19	.15	.18	.11	6
7	Pests and Diseases ...	.32	.16	.10	.18	.23	.15	.10	.07	.11	.14	7
8	Miscellaneous Cultivation ...	.17	.19	.21	.29	.28	.08	.12	.14	.18	.17	8
9	Total Cultivation ...	6.87	6.80	6.73	8.99	7.09	3.09	4.35	4.45	5.53	4.35	9
10	Reaping	2.54	2.53	2.74	2.70	2.77	1.14	1.63	1.81	1.66	1.70	10
11	Manufacture	.97	.83	.72	.98	.88	.44	.53	.48	.61	.54	11
12	Live stock	1.01	.87	1.20	1.23	1.28	.46	.56	.79	.76	.79	12
13	Buildings	.80	.66	.63	.65	1.42	.36	.42	.41	.40	.87	13
14	Taxes	.63	.59	.52	.56	.82	.28	.38	.34	.35	.50	14
	Estate Supplies:											
15	Manures	.01	.01	.02	.01	...	.01	...	.01	...	...	15
16	Feed	.29	.31	.45	.12	.41	.13	.20	.30	.07	.25	16
17	Other	1.18	.64	.81	1.09	1.27	.53	.41	.54	.67	.78	17
18	Total Supplies ...	1.48	.96	1.28	1.22	1.68	.67	.61	.85	.74	1.03	18
19	Miscellaneous	.26	.24	.27	.78	.97	.12	.16	.18	.48	.59	19
20	Roads and Bridges ...	.43	.40	.30	.30	.13	.19	.26	.20	.18	.08	20
22	Total Cost	19.44	18.53	19.04	22.25	23.71	8.75	11.88	12.57	13.69	14.54	22
23	Revenue from Inter-cultivated crops ...	.28	.53	.50	.43	.51	.12	.34	.33	.26	.31	23
24	Cost on Estate	19.16	18.00	18.54	21.82	23.21	8.63	11.54	12.24	13.43	14.23	24
25	Transport to Merchant's Store	.74	.52	.46	.45	.47	.33	.33	.30	.27	.29	25
26	Cost at Merchant's Store ...	19.90	18.52	19.00	22.27	23.68	8.96	11.87	12.54	13.70	14.52	26
29	Revenue from Cacao ...	44.50	31.29	30.91	32.87	33.20	20.02	20.06	20.40	20.21	20.36	29
30	Profit on Cacao	24.60	12.77	11.91	10.60	9.52	11.06	8.19	7.86	6 51	5.84	30
31	Loss on Cacao	...	...	...	...	...	...	...	...	...	...	31
32	Other Expenditure ...	3.18	1.12	1.04	1.55	.69	1.43	.72	.68	.95	.42	32
33	Other Revenue	4.72	1.36	1.60	1.20	.27	2.12	.87	1.05	.74	.16	33
34	Total Expenditure ...	23.08	19.64	20.04	23.82	24.37	10.39	12.59	13.22	14.65	14.94	34
35	Total Revenue	49.22	32.65	32.51	34.07	33.47	22.14	20.93	21.45	20.95	20.52	35
36	Profit	26.14	13.01	12.47	10.25	9.10	11.75	8.34	8.23	6.30	5.58	36
37	Loss	...	...	...	...	...	...	...	...	...	...	37
38	Interest Received... ...	...	...	.01	...	...	...	...	...	...	...	38
39	Interest Paid	3.19	2.62	1.33	.45	1.69	1.44	1.68	.87	.28	1.04	39
40	Net Profit	22.95	10.39	11.15	9.80	7.41	10.31	6.66	7.36	6.02	4.54	40
41	Net Loss	...	...	...	...	...	...	...	...	...	...	41
		Total.					Average.					
42	Cacao Acreage	7,508	15,000	9,151	3,380	1,648	198	231	261	241	165	42
43	No. of Cacao Pickets in 1000's	2,032	4,067	2,509	940	477	53	63	72	67	48	43
44	Valuation in 1000's $ ...	2,007	3,212	2,098	699	286	53	49	60	50	29	44
45	Yield in bags of Cacao ...	16,690	23,397	13,860	5,496	2,687	439	360	396	393	269	45
46	Yield in bags per 1000 pickets	...	...	...	...	...	8.22	5.75	5.52	5.85	5.64	46
47	Yield in lb. per acre ...	...	...	...	...	...	366	257	249	269	269	47
48	Yield in lb. per picket ...	...	...	...	...	...	1.36	.95	.91	.96	.93	48
49	Price of Cacao per fanega in $	...	...	...	...	...	13.35	13.37	13.60	13.47	13.57	49
50	Per cent. return on capital ...	...	...	...	...	...	9.77	6.07	5.44	4.95	5.24	50
51	No. of estates surveyed ...	38	65	35	14	10	...	...	...	...	...	51

STORAGE AND TRANSPORT OF TROPICAL FRUITS AND VEGETABLES.*

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CITRUS.

The citrus fruits of commerce include the many varieties of sweet orange (*Citrus sinensis*), the grapefruit or pomelo (*C. paradisi* = *C. maxima* var. *uvacarpa*), the shaddock or pummelo (*C. maxima*), the mandarin group (*C. nobilis* and its varieties, including the common mandarin or tangerine, the King orange and the Satsuma orange), the lemon (*C. limonica*), the citron (*C. medica*), the lime (*C. aurantifolia*), the sour orange (*C. aurantium*), the kumquats (*Fortunella* spp.) and others. According to Barrett (12) "This great group of food fruits is one of the three oldest in cultivation. It is only in the last half century, however, that citrus fruits have acquired much commercial importance. Several kinds have been cultivated for about 3,000 years."

Although the genus is primarily of tropical origin, the largest producing areas actually lie outside the tropics. Citrus fruits are thus grown under a wide range of cultural conditions in all five continents, from moist tropical regions of uniformly high temperature, to subtropical and warm temperate regions where trees may occasionally suffer from frost injury. Since environment influences not only the growth of the plant but also the physiological behaviour of fruit after it has been harvested, diversity rather than uniformity characterises the storage requirements of citrus produced in different countries.

Oranges and Grapefruit.

Oranges are produced on a large scale, either for export or for local consumption in the United States, various West Indian Islands, Brazil, Spain, Italy, the Levant, Algeria, Tunisia, South Africa, India, Malaya, China, Japan and Australia. Many types are known including the Navels, Bloods, Mediterraneans, Spanish and wild seedlings. Large scale cultivations of grapefruit have been established or are now being developed in many of these regions also.

Under commercial conditions, fruits are removed from the trees, placed in field boxes, quailed (wilted or cured) on the plantation, and transported to the packing shed. Prior to harvesting, and during the several processes between picking and marketing, fruits are liable to mechanical and physiological injury and to fungal invasion and rotting: attention is therefore required to plantation management and to all subsequent operations; the importance of any particular factor varies from one locality to another. Each producing area has therefore its own special problems which must be solved in the light of local experience, preferably with the aid of competent scientific investigation.

Wastage.—Wastage can be divided into two categories (i) blemishes (summarised in a later section) acquired during picking, handling, packing-shed treatment and storage and (ii) fungal rotting.

The fungi responsible for wastage in different countries vary considerably. The green and blue moulds (*Penicillium digitatum* and *P. italicum*) are important as wound parasites gaining access to the tissues through cuts and abrasions acquired during picking and packing (7, 13, 26, 35, 44, 45, 78, 90, 93, 95, 104, 107, 109). Stem-end rots are caused by fungi (chiefly *Diplodia natalensis*, *Botryodiplodia theobromae* and *Phomopsis citri*) believed to be present at the time of harvesting in an inactive state in or on the twigs and stem ends; after picking, particularly at high temperatures, these may progress with considerable rapidity into the tissues of skin and flesh producing characteristic rots (44, 63, 87, 88, 89, 95, 104, 109, 110, 111, 113). *Colletotrichum gloeosporioides*, which causes a leathery or soft brown rot of the skin and slow disorganisation of the flesh, is characteristically present as numerous latent infections (7, 8, 15, 64, 104). The information available indicates that these remain dormant until the resistance of the fruit is decreased by factors such as the normal senescence of tissues, desiccation, chilling, chemical injury, &c.

The handling and storage of citrus may conveniently be divided, in time, into prestorage and storage.

Prestorage.

Grove Sanitation.

Sooner or later in all producing areas the importance of grove sanitation becomes evident. Pruning, spraying and maintenance of a good standard of orchard cultivation have been shown to be important in the control of certain forms of wastage, notably stem-end rot (51, 89). All fallen and wasting fruits should be collected and destroyed before the several moulds have had time to sporulate (84).

Picking.

In picking, special clippers are used to minimise mechanical injuries which may serve as a means of ingress for blue and green moulds and other fungi later (78, 96). In some countries gloves are worn for picking and during all subsequent operations. While it has become almost axiomatic that citrus fruits must be clipped and not pulled, recent investigations by Winston (110) indicate that pulling, provided it does not cause tearing injuries, is not only cheaper than clipping but is advantageous in the control of stem-end rots (*Diplodia natalensis* and *Phomopsis citri*), the removal of the button also removing infections

* Continued from *Tropical Agriculture*, XIV, 4, 1937.

believed to be harboured in the twig near the stem end. No advantage is to be gained by removing buttons when the fruit is quite mature and ready to fall, since the stem-end fungi may have already progressed into the fruit tissues; the same is true of fruit from weak or diseased trees. The rind of tangerines tears too easily for this procedure, but ripe oranges and grapefruit, over a considerable range of maturity, can be pulled successfully, and do not show increased wastage in storage. In the case of Philippine mandarin oranges, where stem-end rotting during storage is important, the advantages of pulling over clipping has been recorded by De Leon (37).

Fruits should not be picked while still covered with dew or immediately after rain: the turgid fruits are easily bruised, and the oil liberated from the rind causes a characteristic superficial brown spotting known as oleocellosis (43, 44, 80). These spots spoil the appearance of fruits and also facilitate fungal penetration. Powell (80) gives the recommendation that "no fruit should be picked when the trees are wet from rain or dew and no fruit should be picked for two or three days (in extreme cases, more) following a long period of rains." For Australian fruit, Tindale (99) has called attention to the necessity of not picking Navel oranges under moist conditions. Instances are known, however, as in the mountain plantations of Dominica, where, of necessity, limes, grapefruit and oranges are almost invariably picked during or immediately after heavy rains, apparently without harmful results. To minimise injury, a protective layer of wood-wool is sometimes used in the field boxes (84).

The upkeep of field boxes or lugs is important; Putterill (83) recommends that all lugs should be dipped in 2½ per cent. formalin before being sent to the groves to be filled.

Quailing.

Because of the highly turgid condition of fruit on picking and the susceptibility of such fruit to mechanical injury during local transportation, a practice is made of quailing (also described as wilting or curing), fruit on the plantation for periods up to several days. In any one locality the quailing period required to give best results may vary during the picking season; it may also be expected to vary from one country to another, according to the normal turgidity of fruits, the rate at which they lose moisture by transpiration, and the desirability, in relation to the pathogenic activity of rot-producing organisms, of curtailing the period during which fruits are exposed to high temperatures. Under Trinidad conditions, for example, because of the rapidity with which fruits lose weight and are attacked by various organisms, the quailing period, at least for grapefruit picked during the dry season, should be reduced to a minimum (64), and fruits placed in cold storage as soon as possible. According to Bates (14), wilting is generally practised by citrus growers in Southern Rhodesia, the freshly picked oranges being held for several days in large rooms or sheds before grading and packing. For South African oranges Powell (80) states that all fruit should be wilted for 3 to 10 days, depending on the time of year and weather conditions, Navel oranges requiring a longer time than other varieties. Wilting is believed to toughen the skin and so render fruit less subject to injury and infection, but more precise evidence on these points has yet to be obtained. For Palestine oranges (75) it has been shown that fruit packed without preliminary wilting shows 3 or 4 times more Penicillium wastage than that wilted for 7 to 10 days; wilting for 3 days was less effective in reducing wastage. Tindale (99) has described experiments with Australian grown Washington Navel oranges in which the fruits were wilted or sweated for periods of 9 to 13 days, and for Valencia Late oranges for 3 to 7 days. Prolonged exposure at high temperatures favours the active growth of certain pathogens already established in or on the fruits or stems. Where fruit is to be subjected to the ethylene treatment, the quailing or wilting period may be considerably curtailed(13).

While prolonged quailing on the plantation—and subsequently—is still favoured in some areas (80, 105) recent researches would appear to indicate that in some countries, at least, the quailing period may be greatly curtailed without increasing fungal rotting and with the advantage of effecting a conservation of moisture in fruits (64). For oranges and grapefruit grown in various parts of South Africa where a wilting period of two days in the grove and 3 to 5 days in the packing-house is usually allowed, Putterill (83) found that packing without wilting was not detrimental. The same author, however, observed that the development of oleocellosis due to rubbing of turgid and gritty fruit on the field boxes was reduced when fruit was wilted for 9 days in the grove, but that wilting for 6 days was not enough to have this effect.

As early as 1914, Mann (66) advocated curtailment of the curing period and early shipment: "Curing is undesirable when it causes delay in the shipping of the fruit." According to Friend and Bach (49), curing grapefruit for 10 days at 70°F. was beneficial in curtailing the extent to which pitting (chill injury) developed subsequently in cold storage. Hawkins (56) also observed that pitting could be reduced by curing fruit for 1 to 3 weeks at 70°F. Fruit should be protected from excessive exposure to bright sunshine after picking.

Conservation of Moisture.

By contrast with quailing operations, designed to reduce various forms of blemishing and wastage, the conservation of moisture in citrus fruits is important on several counts, including the avoidance of shrivelled, unattractive fruit, and additional wastage due to mechanical injury consequent on the development of looseness in packs. Bates (14) mentions that excessive losses during the rail journey to the port of shipment may lead to rejections because of crates being under weight.

A number of factors, including temperature, relative humidity, air movement, condition of fruit at packing, and choice of wrappers, are of practical importance in determining the rate of evaporation from grapefruit and oranges. The biological factors involved include the number of functional stomata, the concentration of flesh and rind solutes, the transference of water between flesh and rind, the thickness of the skin, the structure of cuticle and epidermis and the density of oil vesicles in the rind. Klotz and Haas (62) observed that although there are fewer stomata at the button end than at the stylar end, transpiration is greater from the former, and Hodgson (60) has shown that citrus fruits may act as a water reservoir for the leaves.

Bates (14) has shown that oranges lose water comparatively rapidly for the first 6 to 7 days after picking. Thereafter the rate of loss is comparatively steady over long periods. For practical purposes, the more important conditions controlling moisture loss may be stated as follows : high temperature, low relative humidity or rapid air circulation have a marked effect in increasing loss in weight ; at low temperature, with high relative humidity, slow but adequate air circulation, the moisture content can be greatly conserved. The importance of particular aspects will vary in different countries according to climatic conditions, packing shed transport and cold storage facilities. The advantages of rapid handling, packing, precooling and cold storage are evident in respect of the control of excessive water losses (63, 64).

Packing-Shed Treatment.

On receipt at the packing-shed, different routines are followed in different countries, the fruit being subjected to several processes prior to packing. In many countries the fruit, while still in the field boxes, is first subjected to a borax or other antiseptic dip as a means of controlling green mould and stem-end wastage. Fruits then undergo a further period of quailing (up to 48 hours for Florida grapefruit) to minimise bruising during the passage through the washing and grading machinery. If the skin is green, fruits may be subjected to artificial colouring (ethylene or stove gas treatment) to produce the desired yellow or orange colour. To loosen scale insects and superficial dirt and to facilitate polishing, fruits are also subjected to a dilute caustic wash. From the washing tank they are carried along on rollers to be sprayed with clean water and brushed ; thereafter they are sprayed with a water-wax emulsion and finally dried and polished ; other methods of waxing may also be adopted. From the polishing brushes they are discharged on to moving canvas belts where all bruised or undesirable fruits are culled, the sound fruits passing on to the grading machinery to be segregated for size into different bins. In order that these several operations may be carried through expeditiously, at the same time subjecting fruit to as little rough handling as possible, elaborate but very efficient sets of machinery have been designed. Where the industry is still in its early stages, processing by hand is not uncommon.

Packing-Shed Sanitation.

The major problem in handling, packing and storing citrus is the control of wastage. Careful attention should therefore be given to every aspect of cleanliness and sanitation in the equipment and storage accomodation in the packing-shed.

Chemical Treatments.

Borax dip.—In many countries fruits on arriving at the packing-shed are immersed in a tank containing a 5 to 8 per cent. solution of commercial borax (also 6 parts borax, *i.e.*, sodium tetraborate, and 1 part boric acid, and other borax-boric acid mixtures to give a neutral solution) held at a temperature ranging from 100° to 120°F., the immersion lasting from a few seconds to 4 to 5 minutes. The boxes are then left to drain and restacked. As a rule this treatment has been found efficacious in the control of the common green and blue moulds, and sometimes for the fungi responsible for stem-end rot.

In 1925 Barger and Hawkins (9) reviewed the literature dealing with the use of disinfectants (including potassium permanganate, copper sulphate, formalin, hot water and soap, borax soap, borax, &c.) in washing citrus fruits, and indicated by controlled experiments the value of boric acid and borax solutions in controlling blue and green moulds. The last decade has seen a marked extension of work along these lines in different countries (13, 26, 44, 54, 83, 90, 91, 113). As a recent thorough investigation of the efficacy of borax in controlling wastage, the work of Winston (109) may be cited. Best results were obtained when fruits were dipped immediately on receipt at the packing-shed, delayed treatment being considerably less effective ; an eight per cent. solution of borax, at 80° to 120°F. gave good results, 110°F. being optimal for Florida fruit ; an instantaneous dip, *i.e.*, an immersion of 4 to 5 seconds, was as effective as an immersion of 4 to 5 minutes ; wet fruit, dried slowly so that the borax residue was left on the rind several hours showed greatest control of wastage. Young and Read (113) found that washing Australian Navel and Valencia oranges in 5 per cent. borax at 110° to 120°F. followed by waxing showed marked preservative action. It has been observed that immersion of citrus fruits in a borax solution may sometimes, as well as exercising a fungicidal action, cause a characteristic brown blemishing at the stem-end (13, 26, 109). In the particular instance of Trinidad grapefruit, it has been conclusively demonstrated that the borax treatment not only fails to control Penicillium wastage, for which it is specifically applied, but that rotting caused by other fungi (*Botryodiplodia theobromae* and *Colletotrichum gloeosporioides*) is actually increased fourfold by its use ; in addition to the readily assessable fungal wastage the borax treatment

caused increased loss in weight, and wrinkling of the skin especially round the button end, leading to very marked blemishing (104). (For borax injury, see section on Blemishes). In such instances the use of the borax dip should be discontinued.

Caustic Washes.—Dilute caustic washes, such as 1 to 2 per cent. caustic soda (83), sodium carbonate (44), 3 per cent. sodium bicarbonate (68, 83, 84), sodium silicates (44), sodium hypochlorite (13, 76) and various proprietary preparations (13, 44, 91) and soaps are used, at temperatures ranging from 100° to 115° to 120°F., as a means of removing dirt, scale insects, &c., and as a partial deterrent to fungal rotting. Young and Read (113, 114) obtained good control of wastage by washing Australian Navel and Valencia oranges in 5 per cent. sodium bicarbonate at 110° to 115°F. for eight minutes, followed by spraying with paraffin and wrapping in sulphite papers. A 3 per cent. solution of sodium bicarbonate was found to reduce mould wastage in South African oranges (44, 84). A temperature of 120°F. for 2 to 4 minutes is cited by Fawcett (44) as the danger point for fruit immersed in such washing solutions ; in some instances it may be necessary to keep the temperature at 95° to 100°F. to avoid hot water injury. The use of disinfectant washes including borax should not be regarded as a substitute for careful handling.

Ammonium bicarbonate.—The use of ammonium salts (to produce an atmosphere containing ammonia) has recently been suggested for the prevention of green mould wastage (101). While giving good control of *P. digitatum* ammonium bicarbonate causes serious skin blemishes (13, 53, 84, 104) ; under commercial conditions, therefore, its use cannot be advocated.

Iodine.—The use of iodine, incorporated in fruit wrappers has been described by Tomkins (100) ; the need for exercising caution in using such wraps in different countries has been indicated (103, 104).

Formalin, &c.—Severe damage to fruits as a result of treatment with formalin gas is recorded by Reichert and Littauer (91).

Salicylic acid and *sodium sulphite.*—These substances were not found efficacious in the treatment of Australian oranges (113).

Artificial Colouring.

The discovery that the unsaturated hydrocarbon constituents of stove-gas were able to induce yellow colouring in green citrus fruits (38, 39) has now been put into general use, the gas ethylene being most frequently selected for this purpose. Detailed accounts of the stove-gas and ethylene methods have been published by several workers (10, 13, 17, 20, 24, 25, 52, 55, 58, 59, 65, 82, 94, 95, 102, 112) ; a large portion of the California, Florida and South African crop is now artificially coloured by ethylene.

Denny (38, 39) has shown that no colouring takes place in the absence of O_2 and other workers that colouring is slow with reduced percentage of O_2. Good ventilation is therefore essential to the successful operation of this process. While ethylene, according to Harvey (55) actually *ripens* many fruits, most investigators have found, in regard to citrus, that the ripening effect is negligible (10, 24, 112), or slight only (17, 31). It follows that immature fruit should not be coloured until it shows a satisfactory total soluble solids : acid ratio (*see* Maturity Tests below). The advantages of artificial colouring consist in an extension of the marketing season and increased uniformity in the appearance of packs. The former is accounted for by the fact that in different citrus producing regions the flesh may have attained to physiological and palatable maturity while the skin is still green or greenish yellow, as in Satsuma oranges grown in Alabama (112), Parson Brown oranges and certain grapefruit varieties in Florida (10), Washington Navel oranges in Southern Rhodesia (13), &c. The lag between colour development and maturity resulting from continued rainy or cloudy weather, may readily be corrected by the use of ethylene ; likewise, in those instances where yellowing fruit reverts to the green condition on the tree, ethylene can be used to advantage (13).

Method of Application.—Full descriptions of the stove-gas method are given by Wright (112) and by Barger and Hawkins (10). The use of ethylene, usually supplied in steel cylinders under high pressure, overcomes many of the disadvantages of the stove-gas method and is now generally adopted. For successful colouring, certain conditions must be provided, but these are not the same for all varieties of citrus nor for fruit grown in different regions. Ethylene may be applied to the curing chambers at regular intervals (*e.g.*, a schedule of 2 to 3 applications per day has been recommended) or it may be passed continuously into the chamber incorporated in a stream of " conditioned " air.

Some examples of typical colouring conditions may be cited. For oranges grown in Southern Rhodesia (13) a temperature range of 70° to 80°F., R.H. of 80 per cent., ethylene concentration of 1 in 5,000 (2 or more applications per day) gives the required degree of colouration in 2 to 4½ days ; in the same region Marsh grapefruit colours best between 70° to 75°F., other conditions being the same as for oranges. Temperatures too high or too low, the accumulation of CO_2 in curing rooms to a concentration of more than 1 per cent (52), too immature fruit (*i.e.*, showing less than 35 per cent. colour), or the presence of oil-spray residues are conditions inimical to the ethylene treatment. Similar recommendations have been advanced by Powell and Matthews (82) ; the optimum temperature cited is 80°F., with R.H. 85 to 95 per cent.

For colouring fruit in Florida, a temperature of 80° to 85°F., with R.H. of 90 per cent. is most suitable (108). Ethylene gas is continuously introduced into the circulating air in the room, the rate of application being such as to give 1 part to 30,000 or 50,000 parts of air (the so-called " trickle system "). The time required is 24 to 48 hours, considerable uniformity of colour being usually achieved. In the " shot " system in which

ethylene doses of 1 in 4,000 to 1 in 5,000 parts of air are applied at intervals of 6 to 8 hours, the time required for effective colouring is 72 to 100 hours. In well ventilated rooms the CO_2 concentration should not exceed 0.25 per cent. Winston correctly calls attention to the fact that "colouring" is a misleading term, the ethylene process being essentially one which, by " degreening " the fruit, allows the yellow and orange colours, previously masked, to become apparent.

Ethylene Treatment and Wastage.—The relation between ethylene treatment and disease incidence is important. Prolonged treatment, particularly at high temperatures, tends to increase stem-end rotting when the buttons, through which infection takes place, are left in position. One effect of the ethylene treatment, however, is to cause a loosening of the button : where this takes place, so that buttons do not require to be forcibly removed, a reduction of stem-end rotting has been recorded (57, 95, 111). Reichert and Hellinger (87, 88) report that removal of buttons by ethylene a 29.5°C. (85°F.) successfully controlled Diplodia stem-end rot and did not increase Penicillium wastage. The importance of ethylene treatment in promoting wastage depends on the particular fungi chiefly responsible for wastage in any one locality. Recommendations must accordingly be based on local experience. Physiological blemishing due to the treatment are described in a later section.

Waxing and Polishing.

These operations commonly consist of spraying an emulsion of wax on to washed and dried fruit, which is then polished by being passed over rotating brushes. Various proprietary waxes are on the market. Waxing not only improves the appearance of fruits but reduces loss in weight and blemishing due to desiccation, which is particularly important when the storage period is prolonged (63). In Australia with Navel oranges, no advantage has been obtained—other than an improved appearance—from waxing oranges (28) ; heavy applications actually shortened the life of the fruit ; with Valencia oranges waxing usually lowered the amount of skin browning and had almost as beneficial an effect in reducing stem-end rot as borax. Young and Read (114) found that the application of a paraffin spray to oranges was effective in controlling Alternaria rotting—a disease arising from an infection at the blossom end. Brooks and McColloch (19) found less pitting (chill spots) in heavily waxed than in control fruits stored at 32° to 40°F., the effect being more pronounced at low than at high humidity.

In polishing, resin is sometimes added to the washing solution (108).

Wrapping.

All fruits are wrapped prior to packing. As a rule thin tissue papers are used for this purpose. Where conservation of moisture is an important desideratum, waxed papers, cellophane or tin-foil wraps may be used. Special sulphite wrappers, glazed on one side, have been used in Southern Rhodesia (14). In an extensive survey of wrapping materials, Fifield (46) has shown that considerable advantages, in respect of moisture conservation and control of pitting, due to chilling, accrue from the use of aluminium foil, or water-proof cellophane wrappers.

Packing.

The standard California box or crate measuring 26 ins. by 12 ins. by 12 ins., is now extensively used. The number of fruits per crate varies with the size of the fruit, being from 360-80 for oranges with a diameter range of 2 ins. to 3½ ins., and 150-28 for grapefruit with a diameter range of 3 ins. to 5 1/16 ins. The fruits are pressed firmly into position, the resulting tight, springy pack being such as to permit of shrinkage without the danger of fruits becoming loose in the crate. Other types and sizes of crate are also used.

Skin Blemishes.

Various types of skin blemishing develop during the handling and storage of grapefruit and oranges.

(*a*) *Oleocellosis.*—A " goose-flesh " condition of the superficial tissues, attributable to the action of oil liberated from the vesicles by bruising turgid fruit, may result in the production of small brown blemishes, described as *oleocellosis* (19, 43, 64). The further development of such spots may be influenced by storage conditions. Not only do they spoil the appearance of the fruit but they may serve as a means of ingress for fungi.

(*b*) *Desiccation blemishes.*—These consist of wrinkled or brownish spreading areas, frequently at the stem end and sometimes associated with bruises. Desiccation is also important in intensifying borax and chilling injuries.

(*c*) *Chilling injury, pitting or pox.*—This is fully described in a later Section. The term " scald " has been applied by Friend and Bach (49) to a blemishing characterised by a slight to distinct browning of the rind ; there is usually little or no sunken margin between blemished and normal tissue ; scald may be present as spots, but as a rule larger areas of the fruit surface are involved. The evidence suggests that scald is a manifestation of chilling injury complicated by other factors.

(*d*) *Blemishes of delayed occurrence.*—These have been recorded for grapefruit and oranges in Trinidad (64). On being taken into storage the fruits were apparently quite sound and remained so for some 20 to 30 days at 76°F. Thereafter, extended sunken areas, involving all the cells of the flavedo, and with collapsed oil vesicles, quickly made their appearance. These blemishes or weals, at first yellow, but becoming pale brown on desiccation, developed *en masse*. Cold storage at 45°F. delayed the appearance of weals for upwards of 68 days. This type of blemishing, presumably attributable in the first instance to mechanical injury, *i.e.*, pressure on turgid fruits, is interesting

because it directs attention to the manifestation during senescence of an injury sustained at an earlier stage. Similar blemishes have been recorded by Bates (15). This type of blemishing is probably due to desiccation rather than to fungi. Nelson (71) also observed a surface blemish of oranges which he calls " Brown Stain " occurring in storage on long delayed shipments. It was important at low temperatures in marine shipments of oranges in transit for more than three weeks, being manifest as a brown staining of the skin or flavedo. In the beginning this was not accompanied by any depression of the surface cells but later, after the fruit had been exposed to drying for some time, the affected tissue became leathery and shrivelled with the oil vesicles slightly sunken below the level of the surrounding cells. From the observation that similar blemishes are produced by exposing fruit to various volatiles, Nelson suggests that the blemishes under consideration are caused by the action of certain cumulative products of the orange itself.

(*e*) *Chemical injury.*—Nelson (71) has pointed out that several substances, notably aldehydes, acetates and esters, are capable of simulating storage blemishes of citrus fruits. For example, exposure to acetaldehyde vapour resulted in the development of skin lesions or blemishes closely resembling those sometimes observed in cold storage. Bates (15) has also observed skin lesions, somewhat resembling pitting due to chilling, in oranges exposed to the vapour of certain chemicals, including paraldehyde and ammonia. When oranges were exposed for comparatively long periods to paraldehyde, they showed little blemishing immediately after removal, but developed severe injury within a few days. The stem-end tissues of sound oranges, especially those on the shoulder of the fruit, were most susceptible to injury.

Blemishing due to borax treatment has already been mentioned. Commencing as slightly sunken, reddish-brown patches of irregular outline, with the oil glands further sunken, the blemishes slowly spread during cold storage. If this is prolonged the blemishes become livid pink patches which may cover half or more of the surface (104). Three main locations of the initial blemish have been observed : (i) immediately under the button, (ii) in a circle about 1 cm. radius from the button, and (iii) equatorially on the fruit corresponding with bruised areas. It is noteworthy that normal desiccation blemishes appear in almost identical positions during cold storage. Development of fungal growth, chiefly *Colletotrichum gloeosporioides*, on these patches is usually postponed until the fruit is transferred to a higher temperature. Individual fruits appear to differ very considerably in their resistance to borax injury, some showing no evidence whatever of damage (104).

(*f*) *Blemishes due to accumulated gases.*—During the ethylene treatment of oranges a brown spotting or discolouration of the rind may be induced if the ethylene concentration is excessive, *i.e.*, greater than 1 in 5,000, or if the temperature is too high (82). In respiration experiments in which grapefruit were enclosed in containers and the respired gases allowed to accumulate with consequent decreasing oxygen concentrations, for 9 days at 75°F., mottled, reddish-brown, sunken areas developed on the skin of some but not all of the fruits (64). It has been found that exposure to relatively low concentrations of CO_2 may increase fungal wastage without the production of physiological blemishes (64). Nelson (71) has recorded blemishes on grapefruit stored in an atmosphere of nitrogen at 70°F. for four days, the gas content of the containers being changed every 24 hours, and at 77°F. after seven days in air stirred constantly but not renewed.

A soggy breakdown of Florida citrus fruits in storage was found to be due to an excess of CO_2 in the atmosphere ; it was found possible to prevent it by constant removal of the accumulating CO_2. Grapefruit kept in an atmosphere of nitrogen, with removal of CO_2 by absorption, is reported to have kept in excellent condition for five months without deterioration in appearance or flavour (47).

Barker (11) states that oranges injured by exposure to high CO_2 and low O_2 concentrations are dull brown in colour and sodden to the touch ; the inner part of the rind is injected and the flesh has a characteristic bitter flavour and unpleasant smell ; a marked development of white spots may be observed on the carpel walls. In slightly injured fruits areas of the skin are often sunken or discoloured and the flavour is slightly bitter. In experiments with Spanish and South African Navel oranges it was found that the orange is less liable to injury from high concentrations of CO_2 than the apple. Oranges which are apparently uninjured during the period of exposure to gas storage conditions may subsequently show rapid wastage. Oranges held in a 12 per cent. CO_2 and 8 per cent. O_2 mixture at 41°F. showed no effect up to 5 weeks but developed a slightly unpleasant flavour by the ninth week ; by comparison with control fruit in air wastage was normal. Higher concentrations of CO_2, upwards of 27 per cent., in conjunction with low O_2 concentrations, 0.5 per cent., 4.0 to 6.0 per cent., were conducive to the abnormal wastage and flavour described above. As a practical issue, concerning the accumulation of CO_2 in ships' holds, the highest CO_2 concentration recorded at Southampton in South African orange shipments was 11.5 per cent. (34). Barker (11) also observed that gas injury was more severe at lower temperatures, *e.g.*, 45°F. and 55°F. Exposure to high CO_2 and low O_2 concentrations results in a marked increase in alcohol content (5, 72).

(*g*) *Collapse.*—This is a condition of general physiological breakdown of the fruit which occurs at the end of its storage life. In the very early

stages it is characterised by a loss of flavour, and sometimes by the development of a bitter taste. Later, the skin becomes dull in appearance, and the white pulp yellowish in colour and sodden in texture, whilst still later the rind becomes soft and fawn-coloured, and infections of both green and blue moulds may appear, generally as numerous small colonies on the softened area (114).

Blemishes and Fungal Wastage.—Difficulty is frequently experienced in distinguishing between the several types of skin blemish observed on citrus fruits when they have reached the market in temperate countries : without a full and accurate knowledge of the pre-storage history, remedial measures cannot satisfactorily be prescribed. This is due chiefly to the fact that it is only in the early stages that clear distinctions are to be found between the different types of skin injury. Once desiccation and fungal wastage have occured the several types of blemish become very similar. In this connection Bates (15) has commented on the resemblance between physiological skin injuries and fungal wastage : " There is a close connection between these two types of storage loss since physiological skin injuries undoubtedly prepare the way for greater losses due to decay fungi. Furthermore, certain types of physiological injury closely resemble the skin decays caused by some fungi, particularly in the early stages. Separation of such blemishes cannot always be satisfactorily accomplished, even by cultural isolations for the presence of fungi or by microscopical examination of the affected tissues." Hawkins (56) also notes that pitting (*i.e.*, chill blemishing) has all the external appearances of injury considered to be due to *Colletotrichum gloeosporioides*. Since this fungus is present in abundance in the superficial tissues of all Trinidad citrus fruit (8) the use of mycological technique will invariably indicate its presence : the primary cause of the blemish, however, may be physiological.

Maturity Tests and Export Regulations.

During the ripening of grapefruit and oranges, there is an increase in the amount of sugars and total solids, and a decrease in titratable acidity (13, 31, 32, 33, 40, 41, 70, 81). Estimations of sugar and acid content accordingly afford a chemical means of determining approximately when fruit is sufficiently ripe to be picked for export. The maturity test in general use is based on the ratio of sugars or soluble solids to acid (calculated as anhydrous citric acid) present in the juice. In California (6, 70) and Florida (27) the ratio of 8 to 1 is accepted as the maturity standard for oranges ; when fruits are 70 per cent. coloured at the time of picking, a minimum ratio of 6 to 1 is allowed ; on the other hand no fruit may be artificially coloured unless the ratio is at least 8 to 1. This ratio is not universally acceptable : thus in Southern Rhodesia (13) a ratio of 6.5 to 1 is regarded as adequate for oranges. For South African fruit generally, Powell (81) writing in 1933 makes the following comment :—

" Undoubtedly the weakest point in the standards governing the quality of export fruit is that of maturity. The existing regulations call for a minimum sugar to acid ratio of 6.5 to 1 for Navels ; 6.0 to 1 for Valencias and other named varieties and 5.5 to 1 for seedlings. The shipment of any variety before it reaches a sugar to acid ratio of at least 7 to 1 is an extremely short-sighted policy. Shipment of immature and sour fruit reacts unfavourably on the industry as a whole and every effort should be made to increase the existing standards of maturity. The chief difficulty in this respect is encountered with a large proportion of the western Transvaal seedlings which become fully mature before they are sweet and palatable. They cannot be left on the trees to sweeten up as they tend to become puffy and drop from the tree. Many of these seedlings do not show a sugar to acid ratio greater than 6 to 1 and a considerable proportion show a narrower ratio even when fully ripe. The sugar content is satisfactory, but the acid content is abnormally high. The reason for this sourness of the fruit when mature is probably an inherent characteristic influenced only to a minor degree by environment." (81).

The ratios set out above should be compared with those adopted in 1928 (40), when more acid fruit was accepted for export (5.0 to 1 for seedlings ; 5.5 to 1 for Valencias ; 6.0 to 1 for Navels). By raising the ratios from time to time, progressive improvements in quality have been effected.

During ripening, although the sugar fraction increases, it is subject to some fluctuation, whereas the acid content decreases uniformly. Accordingly, for Australian citrus fruit, the acidity test is considered the most useful, the number of c.c of decinormal caustic soda to neutralise 10 cc. of juice being used in maturity tests (16). Oranges no longer sour to the palate require approximately 23 cc. of $\frac{N}{10}$ caustic soda, sweet fruit 20 cc. or less, sour fruit 26 cc. or more ; the 23 cc. test is accepted as a suitable standard for marketing.

In California and Arizona Marsh grapefruit of satisfactory palatability the total solids to acid ratio varied according to the district from which fruit was obtained. Ratios varied from 6.8 to 1 in fruit grown in the drier districts to 5.5 to 1 in fruit grown in regions of higher rainfall (6).

For oranges grown in Jamaica, Croucher (33) considers that fruit having a total solids to acid ratio of less than 8 to 1 could be considered mature ; for grapefruit a ratio of 7.5 to 1 might probably be accepted as suitable. An alternative maturity test has been suggested by this investigator.

Maturity tests do not afford an exact indication of palatability. With Rhodesian Navel oranges, picked towards the end of the season, Bates (13), found that with as little as 0.5 per cent. acids, flavour was excellent provided the soluble solid

content was greater than 10 per cent. In prolonged storage trials with Trinidad grapefruit it was observed that flavour was poor although the titratable acidity remained relatively high (64).

Camargo (21) states that Brazilian oranges should be picked when quite mature.

The juice content of fruit intended for export is also important. In South Africa, for example, a certain proportion of the fruit produced, particularly Navel oranges grown under unsuitable conditions, is lacking in juice content. The export regulations specify that Valencias, and other late varieties shall contain at least 45 per cent. of juice by weight and that Navels, seedlings and mid-season varieties shall contain at least 42 per cent. of juice (81). Powell (81) considers that the requirements for Navels and mid-season varieties could be raised to 45 per cent., placing these varieties on the same basis as Valencias and other late varieties.

Pre-Storage Delay.

As a rule several days elapse between picking and the placing of crated fruit in cold storage. In some instances, because of the necessity for quailing, considerable pre-storage delay may be unavoidable. During this period, at tropical or subtropical air temperatures, the several fungal pathogens may make more or less rapid inroads into the fruit. Indeed, the inception of the more serious aspects of wastage can frequently be attributed to this phase in the handling of fruit. Considerable and undesirable losses in moisture may also be sustained if the period of exposure at high temperatures is unduly prolonged. Reduction of the period between picking and cold storage is therefore generally advised both in respect of oranges and grapefruit (63, 64).

Storage.

Non-Refrigerated Transport.

While the use of refrigeration is generally advisable in the storage of citrus there are occasions when fruit must be shipped as ordinary cargo without refrigeration. The question then arises as to the length of storage life that may be expected without excessive wastage. At the higher temperatures several important contingencies have to be considered: chief among these are the facts that senescence, loss in moisture (with concomitant wrinkling and superficial blemishing) and fungal wastage proceed more rapidly. In experiments with Trinidad grapefruit, in which fruits were subjected to conditions simulating non-refrigerated transport to England, Leonard (63) found that this method, whilst involving increased fungal wastage and desiccational blemishing, could be resorted to in the absence of refrigerated transport.

In 1923 McClelland *et al.* (69) reported that if precooled to 50°F., citrus fruits could be shipped from Porto Rico to New York in the ventilated holds of non-refrigerated ships, with satisfactory results, since the hold temperature did not rise much above 60°F.

Palestine citrus fruits (75) are normally shipped in ventilated but non-refrigerated holds, funnel ventilators and fans being used to maintain the flow of air. " Refrigeration is never employed and is generally considered to be unnecessary in view of the shortness of the voyage which normally occupies two to three weeks " (1933). In the holds, humidity is generally high. " As a rule the atmosphere is very close when a hold is first opened, while considerable quantities of condensed moisture are often present on the roof and sides of the chambers where local cooling has taken place. In some instances this is so extensive that the upper cases are soaked by ' drip ' from the roof." At loading, hold temperatures of 62° to 68°F. sometimes as high as 70°F. and as low as 55°F. have been recorded.

On arrival at English ports wide temperature variations between and within holds are found, as much as 20°F. in one cargo being not unusual: highest temperatures 72° to 73°F.; lowest temperatures 44° to 48°F.; average range 50° to 65°F. The conduction of heat from the fruit to the sides of the ship is probably the most important agency in reducing the temperature of Palestine orange cargoes. Wastage recorded in crates on arrival ranges from 2 to 50 per cent. Powell (79) in 1925, stated that the usual amount of decay was from 10 to 25 per cent., but this estimate is thought to be on the high side, since even in a " wasty " cargo a large proportion of crates contains only 0 to 5 per cent. of rotted fruits. In general the extent of wastage is now (1933) considered to be in the vicinity of 5 per cent. —a loss estimated at £135,000 for 1928-29. In this wastage, blue and green moulds and Diplodia stem-end rot are the most important.

The possibility of storing Philippine-grown oranges in non-refrigerated but ventilated underground storage rooms has been considered by De Leon (37). A storage life of 6 weeks was obtained with fruits which had been previously treated with 0.018 per cent. potassium permanganate for 5 minutes. Wastage, however, was considerable. Later experiments showed that untreated fruits kept about as well as permanganate-treated fruits during the first five weeks in storage: wastage was more pronounced in treated fruits during the second five weeks.

Humidity in Storage Rooms.

According to Allen and Pentzer (3) grapefruit and oranges require a R.H. of 88 to 92 per cent. in the storage rooms. Provided the air does not become stagnant a R.H. as high as 93 per cent. may not be harmful. In fruit held at 95 per cent. R.H. without air circulation superficial mould tends to appear at the button end. On the other hand at relatively low humidities, 80 per cent. or under, there is a severe risk of wilting and softening of fruit.

Storage Temperatures.

General.—Investigations in different countries on the cold storage temperatures required for oranges and grapefruit show a considerable range. The earlier records for grapefruit, for example, are characterised by citations of comparatively low temperatures—below 40°F.—but as knowledge of chilling or low temperature injury has increased, progressively higher storage temperatures—above 45°F.—have been recommended, particularly where prolonged storage is required. Early cold storage, rapid cooling to the required temperature, with avoidance of chilling (see later Section) and thereafter maintenance of uniform temperatures and high R.H. (88 to 92 per cent.) are advisable for both oranges and grapefruit. In general the temperature selected should be such as to give the maximum control of fungal rotting with minimum development of physiological breakdown.

" It seems advisable in order to avoid the danger of serious physiological breakdown in most citrus fruits, to hold them at a temperature rather higher than that most ideal for preventing all fungal decay. Some decay from fungus development is, in most cases, probably less injurious than general spotting and breakdown of the fruit from physiological derangement." (44.)

Precooling.—Precooling ensures that fruits are cooled rapidly to the temperature of transport and has the advantage of giving uniformity of temperature throughout the hold. In South Africa oranges are pre-cooled to 40°F. before being loaded into the ships (85, 92). Precooling is also in common use in the United States, prior to the loading of refrigerator rail cars. If not precooled, it usually takes 3 to 4 days in the refrigerator car before the desired temperatures are reached (67). Recently constructed precooling plants in California have refrigeration equipment capable of cooling large consignments from 95°F. to 36°F., the usual precooling temperature, in 60 hours (73). In Florida, precooling is generally practised before fruit is loaded into refrigerator cars (108). Precooling rooms are provided with an air blast system by which the air, at 32°F., is changed about 2½ times per minute. The temperature of fruit is thus brought below 40°F. in 24 hours. Thereafter fruit is held at 40° to 45°F.

Precooling of Australian oranges intended for export has been recommended (85); according to regulations laid down in 1933 it is advised that Australian oranges intended for export must be precooled to a temperature not lower than 38°F. and not higher than 42°F. (4).

Overland Transport.—The special problems of overland transport of citrus fruits in refrigerator cars have been fully considered in a recent publication by Mann and Cooper (67).

(*To be continued.*)

REVIEW.

LIVESTOCK OF SOUTH INDIA.

By R. W. Littlewood, *Madras Government Press*, Madras, 1936. pp. viii + 239. Rs. 4-2.

The author has held the position of Deputy Director of Agriculture, Livestock, in Madras for a period of 17 years, for he succeeded the present reviewer in 1919. It is unusual for one officer to remain so long in one place—it would hardly be possible in Colonial Service—but the publication of this work reveals the intimate knowledge which the author has been able to acquire of his cattle and helps us to realise the importance which the Royal Commission on Agriculture in India attached to continuity of policy in all schemes for livestock improvement. Captain Littlewood's knowledge covers not only the many different breeds existing in South India, but includes the question of breeding improved cattle suitable to the conditions of the country, and extends to their feeding, either by natural grazing or by artificially-grown foods. The result is that the present work is full of information, much of it of course only of local value, but a surprisingly large proportion of value to workers in the subject of livestock improvement in our tropical Empire. Trees for instance, are of considerable importance in pastures in dry areas, and Captain Littlewood describes the practice of folding goats on the land in order to secure a good stand of *Acacia arabica* seedlings, which spring up from their droppings. An adaptation of this practice might be quite useful elsewhere, for it is in dry districts, or districts liable to dry spells, that cattle breeding naturally seems to take root: the peasant has perforce to take considerable pains to preserve his fodder against times of scarcity and this leads to his taking greater care in the feeding and management of his livestock.

Such indeed is the importance of his stock to the dweller in these areas that it is surprising to find that so little is being done to help him. The high value of the export of animal by-products from our tropical colonies is increasing and serves as an additional incentive to an increased appreciation of the value of an Animal Husbandry Department. In Nigeria for instance, the export trade in *ghi* has increased from 1,634 lbs. in 1931 to 250 tons in 1935, while in Tanganyika, the increase in the value of the hides exported, that could be brought about by a very simple improvement in their method of preparation would, if it was adopted, run to many thousands of pounds annually.

It is books such as the present which help to keep before the public both the importance and the intricacy of the live stock industry, and this work is therefore particularly welcome. Its appeal would be increased, if more care had been taken to explain such local expressions as bandy, poramboke, or patta, which familiar though they are in Madras, probably convey little to the outside reader. The illustrations are numerous; the best are excellent, but there are too many poor ones. It is unfortunate that a book completed in January, 1935, should not be published until October, 1936.

A former Deputy Director of Agriculture, Livestock, Madras.

OBITUARY.

Sir James Currie, K.C.M.G., K.B.E.

Sir James Currie who was Chairman of the Governing Body of the Imperial College of Tropical Agriculture and whose death took place at Corpus Christi College, Cambridge, on 17th March, had a distinguished career. The son of the late Rev. James Currie, LL.D., he was educated at Fettes College where he was an open scholar. He obtained an exhibition to Edinburgh University and in 1888 was elected a scholar of Lincoln College, Oxford. In 1899 he joined the Sudan Civil Service and in the following year was appointed both Principal of the newly founded Gordon College, Khartoum, and Director of Education in the Sudan. These posts he held until the end of March, 1914. He became a member of the Governor-General's Council for the Sudan in 1911 and was on terms of friendship with the late Lord Kitchener. Shortly after war broke out he returned to England where his great administrative ability found him, in 1916, as voluntary Director of the Training Munition Workers Labour Supply Department, a post which he held until 1918 when he joined the Ministry of Labour, again in a voluntary capacity, as Controller of the Training Department.

In 1922 Sir James Currie became Director of the Empire Cotton Growing Corporation which has not only been mainly responsible for the progress made during recent years in the production of cotton in the Empire but has also played a leading part in insuring the provision of adequate training facilities for its agricultural research staff in the tropics. This was a subject very dear to Sir James and he and his great friend and colleague, Sir Arthur Shipley, were largely instrumental in initiating the existing Colonial Agricultural Scholarship scheme. Having always the welfare of the Sudan very much at heart he had urged for a long time that a proper system for recruiting cadets for the development of that country's agricultural resources was necessary and it must have been a great source of satisfaction to him to know, before his death, that the Sudan Government had finally decided to establish an Agricultural Scholarship scheme based on that which had proved so successful for the Colonial Office and the Empire Cotton Growing Corporation. He had a very wide knowledge and considerable experience of educational matters and two years ago was a member of the Government Committee appointed to enquire into the status of various agricultural colleges in Great Britain. At the time of his death he was a member of the Government Committee which was investigating veterinary education in England. He was also Chairman of Governors of Dauntsey School, a Governor of Marlborough College, of the Imperial College of Science and Technology, and took the keenest interest in the Loughborough Engineering College.

It is difficult to estimate Sir James' services to the College. He became Chairman of the Governing Body in 1927 on the death of Sir Arthur Shipley and his strong character, devotion to the cause of agricultural education, and immense knowledge of affairs and people in general made him the obvious choice for this post. The responsibility was a great one as the College was in its early stages of development and had not yet had time to become properly established. Its research activities had only just begun, while the students who had been trained had not had the opportunity of demonstrating the value of their College training. The provision of necessary funds was a continuous source of worry and anxiety, but it was largely due to the determination, faith and enthusiasm with which he and his colleagues in the Governing Body tackled these problems that the danger period during the slump of 1932 was successfully overcome.

His personal interest in the College was great and in spite of his many engagements, he found time to pay two separate visits of several weeks duration to the College early in 1929 and 1934, in order to obtain first hand knowledge of all the aspects of its activities. During these visits he took special pains to get into personal touch with every member of the Staff, and by his kindliness and consideration endeared himself to all. He was immensely proud of the progress that had been made during his period of office, and was indefatigable in furthering the interests of the College both at home and in the Colonies.

His character was forceful, and he had the happy knack of saying the right thing at the appropriate moment and of cutting through the frills and getting down to essentials.

Sir James in his leisure moments was a gentleman farmer, and had a large estate in Wiltshire where he was keenly interested in the progressive movements that are now taking place in British agriculture. Those of us who have been privileged to visit him at Upham House will never forget the hospitable welcome invariably accorded in that delightful country retreat, by Sir James and Lady Currie.

The deepest sympathy is felt by all members of the College for Lady Currie in her great bereavement.

The late Sir JAMES CURRIE, K.C.M.G., K.B.E.

EMASCULATION OF SUGAR-CANE FLOWERS.

See page 128.

PRELIMINARY REPORT ON TERMITES AND TERMITE DAMAGE IN TRINIDAD, WEST INDIES.

By A. M. Adamson.
(*Imperial College of Tropical Agriculture*).

I.—Introduction.

In 1933 a survey of the termite fauna of Trinidad was undertaken by the writer and, though it has been subsidiary to other work, collections from over 1,000 colonies have been made in many parts of the island. Probably about three-quarters of the species present have been found. A few termites have also been taken during brief visits to many of the Leeward and Windward Islands, in the course of two slow voyages between Trinidad and New York. Only part of these collections has been studied systematically, and a survey of damage in buildings has only recently been begun. But since scarcely anything has been written on the termite fauna of Trinidad, and since the damage is very extensive and in certain cases easily preventable, it seems advisable to publish a preliminary report now, rather than to await the results of more extensive study.

Previous literature on the termites of Trinidad is limited to records of a few species. Fortunately, however, those of British Guiana have been extensively studied by Dr. A. E. Emerson, at the Tropical Research Station of the New York Zoological Society at Kartabo. Most of the Trinidad species occur also in British Guiana and descriptions of them are therefore to be found in Emerson's paper (1925).

The main object of this report being the reduction of termite damage, it has been written in the form in which it may, perhaps, be of widest use. Matters of most direct practical importance have been placed in parts V and VI, other topics in parts I to IV. A table on page 146 should make it easy to determine the species of termites commonly found damaging buildings and other structures, and thus to select the methods of control that may be applicable.

It is a great pleasure to acknowledge the kindness of Dr. A. E. Emerson, of the University of Chicago, who has not only confirmed my identifications of many species, but has also provided an unpublished list of the termites which he has collected in Trinidad, and notes on their nomenclature; of Dr. S. F. Light, University of California, who examined part of my collections; and of Mr. R. L. Brooks, Conservator of Forests, Trinidad, and Mr. C. Swabey, Assistant Conservator, who have given information on local timbers and also provided facilities for field work.

II.—List of Termites known in Trinidad.

The following list of Trinidad termites includes: (1) The species recorded from Trinidad in Emerson's (1925) report on the termites of British Guiana (marked*); (2) the additional genera and species collected here by Dr. Emerson and recorded in the unpublished list already acknowledged, but not included in his British Guiana report (marked†); and (3) those in the writer's collection that have thus far been determined, including most of those collected by Dr. Emerson, and a few others (unmarked). Further study of the writer's collections will probably add some ten or more species and the list as it stands below, therefore, probably includes not much more than half of the species occurring in Trinidad.

The nomenclature used below and throughout this paper is based on information kindly given by Dr. Emerson, who writes (*in litt.*, 1937): "The generic names as given in this list are the best at present. In several instances subgenera have been raised to generic rank and in one case the name has been changed from *Mirotermes* to *Termes* . . ." Other changes are noted in the foot-note to the list.

Kalotermitidae.

1. *Kalotermes* n. sp.†
2. *Rugitermes* n. sp.†
3. *Cryptotermes brevis* (Walker)
4. do. n. sp.†
5. do. sp. or spp., undet.
6. *Glyptotermes* n. sp.†
7. *Calcaritermes nigriceps* Emerson†

Rhinotermitidae.

8. *Heterotermes tenuis* (Hagen)†
9. *Coptotermes testaceus* (L.)* (1)
10. *Rhinotermes longilabius* Emerson†

Termitidae.

11. *Cornitermes* (*Labiotermes*) *labralis* Holmgren*
12. *Armitermes* (*Armitermes*) *holmgreni* Snyder† (1)
13. *Obtusitermes* n. sp.†
14. *Nasutitermes costalis* (Holmgren)*
15. do. *ephratae* (Holmgren)*
16. do. *guayanae* (Holmgren)†
17. do. *intermedius* Banks*
18. do. sp. or spp., undet.
19. *Subulitermes parvellus* (Silvestri)*
20. do. *snyderi* Emerson*
21. do. n. spp.†
22. *Anoplotermes brevipilus* Emerson†
23. *Crepititermes verruculosus* Emerson
24. *Termes hispaniolae* (Banks)* (1)
25. do. n. sp.† (1)
26. *Cavitermes tuberosus* Emerson*
27. *Neocapritermes angusticeps* Emerson
28. *Microcerotermes arboreus* Emerson*
29. do. sp., undet.

(1) Changes in nomenclature of these species have been made by Dr. A. E. Emerson (*in. litt.*, 1937), as follows: *Coptotermes marabitanas* (Hagen) is a synonym of *C. testaceus* (L.). *Armitermes holmgreni* Snyder was recorded from Trinidad as *A. albidus* (Hagen) by Emerson (1925). *Termes hispaniolae* (Banks) is the correct name for *Mirotermes hispaniolae* Banks. The species referred to above as *Termes* n. sp. was recorded from British Guiana by Emerson (1925) as *Mirotermes nigritus* (Silvestri).

III.—General Features of the Termite Fauna.

As the above list shows, the termite fauna of Trinidad is rich and varied, the number of genera being at least 20 and of species probably over 50. Their individual numbers are so great that almost all dead wood in a natural state harbours termites and a high proportion of buildings, in town and country alike, is to some extent infested by them.

All the three families (in the system of classification adopted by Light, Emerson, Snyder and others) known in the New World are represented in Trinidad, though it is surprising to find only three of the Rhinotermitidae in the above list. The remaining families are the Hodotermitidae, which are confined to Africa and Central Asia, and the Mastotermitidae, with a single species in North Australia.

The most conspicuous termite dwellings in Trinidad are the so-called "carton", "niggerhead" and earthy nests built on tree-trunks, fences, &c., at heights of up to 30 feet and more from the ground, with which they are in communication by means of covered passages or runways. The commonest nests of this type are the earthy or mud-like nests of *Microcerotermes arboreus* (fig. 5) and the "niggerhead" nests, containing less earth and usually reddish-brown in colour, of *Nasutitermes costalis* (fig. 3). The dwellings of other arboreal species of *Nasutitermes* are less abundant than these. The termite mounds characteristic of many tropical countries, especially Africa and Australia but also South America, are uncommon in Trinidad, where the only true mound dwellings that I have seen are those of a rather small species of *Nasutitermes* (fig. 2), which do not exceed about two feet in height. They are common on the Aripo, Piarco and Mausica Savannahs, and doubtless in similar habitats. Many forest species, however, build their nests in and around the base of tree-trunks and dead stumps, the decay and removal of which may leave the nest standing alone. It is usually obvious that the mound-like form of these nests has been acquired secondarily. The largest nests of this kind that I have found in Trinidad are those of *Cornitermes labralis*, which may be four feet long by two feet in diameter. These nests, however, occur mostly in dense forest, and are therefore less conspicuous features of the landscape than those of *Microcerotermes* and *Nasutitermes*. The low nests of several species of *Nasutitermes*, *Armitermes* and other genera escape notice because their surface is earthy and often obscured by dead leaves. All of the Rhinotermitidae and many of the Termitidae have underground nests which are seldom seen and indeed often very difficult to discover, though members of the colonies may be found abundantly in dead wood above ground. All of the Kalotermitidae, in Trinidad as elsewhere, live only in the galleries which they excavate in wood, building no nest whatever.

Most species of termites in Trinidad appear to be distributed very widely over the island, with little restriction as regards such conditions as altitude, soil and flora. Many genera, such as *Cornitermes*, *Rhinotermes*, *Armitermes* and *Neocapritermes*, have been found only in forests, but it seems to make little difference whether the forest be primaeval or secondary. A few species occur almost everywhere where dead wood is found. The most widely distributed of all is the destructive *Heterotermes tenuis*.

The majority of Trinidad termites occur also in British Guiana and the fauna may be regarded as a reduced replica of that of the adjacent mainland, though the termites of Venezuela, the nearest country, are little known. Between Trinidad and the Lesser Antillean islands to the north a much greater reduction of species appears to occur, though several well-known species, such as *Nasutitermes costalis*, *Heterotermes tenuis* and *Cryptotermes brevis*, extend throughout most of these islands. The possibility of introduction by human commerce must be remembered, and in any case the fauna of the islands has been little studied. In Puerto Rico, Wolcott (1936) lists only 16 species, of which at least four occur also in Trinidad.

Swarming of alate or winged termites (known locally as "rain-flies", though the term is applied also to some true ants) is most active in the early months of the rainy season, which normally begins late in April or in May. Nymphs with wingbuds are common in colonies from March onwards, and fully developed alates in May and June. In the rainy season of 1936 (unfortunately the only one that I have spent in Trinidad) the greatest activity observed in the neighbourhood of St. Augustine occurred on 11th July, about two months after the rains began. Heavy showers fell throughout the morning and the sky was overcast all day. Between noon and 5 p.m., within a radius of about two miles, swarms of at least six species were seen. The greatest swarm was that of *Coptotermes testaceus*. Occasional alates of several species of the Kalotermitidae have been caught at lights during almost all months of the year.

The insect guests of termites in Trinidad are numerous and interesting. Many of them have been collected by Professor F. W. Urich, but little has yet been written about them. The Protozoan fauna of termite intestines has not yet been studied. It is hoped that collections may soon be made.

Damage by termites in Trinidad, which is discussed in more detail in part V, is widespread and costly, though proceeding less rapidly than in many other tropical countries. Two species—*Cryptotermes brevis*, a dry-wood termite, and *Heterotermes tenuis*, which is subterranean—appear to be responsible for most of the damage in buildings. *Coptotermes testaceus*, though belonging to one of the most destructive genera in many countries, has thus far been found in few buildings here. The common builders of exposed nests, *Microcerotermes arboreus* and *Nasutitermes costalis*, have rarely been found attacking sound wood in buildings. Damage

to living plants appears to be of insignificant extent, but little attempt has yet been made to determine its importance.

The beneficial rôle of termites in the disintegration of dead wood in forests is as apparent in Trinidad as elsewhere. Their status in relation to fertility of soils, recently discussed at the Imperial Entomological Conference in London in 1935 will, if possible, be investigated soon.

IV.—Notes on Individual Genera and Species.

Family Kalotermitidae.

The Kalotermitidae are the "dry-wood" termites, so called because their habitations are restricted to the galleries excavated in wood, which is usually hard and dry. They are thus sharply distinguished from other termites, which require contact with the ground and thus to water, by a feature of great practical significance. The Kalotermitidae are further distinguished by their lack of constructions, by the presence in their galleries of small, hard faecal pellets of uniform size and shape, and by the absence of a worker caste, the labourers of the colony being immature forms of the reproductive caste.

With the exception of *Cryptotermes*, the Kalotermitidae of Trinidad appear to be of little economic importance. They are seldom seen except as winged forms and though they have been collected fairly extensively, little systematic work on them has yet been done. It must therefore suffice to note that about a dozen species in five or more genera—*Kalotermes*, *Rugitermes*, *Cryptotermes*, and *Calcaritermes*—have been collected and that many of them appear to be undescribed.

Cryptotermes brevis (Walker), the most destructive dry-wood termite in Trinidad, is widely distributed in the New World, probably occurring in most countries between Florida and Mexico in the north to Brazil or still farther in the south, and probably in all or almost all of the West Indies. This distribution may have been acquired to a considerable extent by human commerce. In Trinidad as elsewhere it has been recorded only in buildings, its native habitat being apparently unknown. At least two other species of *Cryptotermes* have been found not uncommonly in natural habitats in Trinidad, indicating that *C. brevis*, if it occurs at all outside buildings, must be relatively rare, to escape notice. Alates have been found in colonies especially between April and June. Large swarms have been observed, usually between 6.30 and 8 p.m., in May and June, and occasional flying alates at many different times of the year.

A second species of *Cryptotermes*, not yet determined, has been found in a few buildings. It may be more destructive than collections to date suggest, but its importance is probably small in comparison with *C. brevis*. Soldiers of the two species are superficially similar, though very different under magnification. The undetermined species has been found in the open, in dead branches and stumps, more often than in houses.

Family Rhinotermitidae.

The Rhinotermitidae include relatively few genera, but some of them are almost world-wide and very destructive, especially *Coptotermes* and *Heterotermes*, which occur in Trinidad, and *Reticulitermes*, one of the most destructive genera in North America. The family is readily distinguished from the Kalotermitidae by the underground nests, the covered passages leading to wood not in contact with the ground, and by the slender mandibles, devoid of conspicuous teeth, of the soldiers of most species. From the Termitidae this family is equally clearly separable by the flat pronotum of workers and soldiers and by the large anterior wing-scale, overlapping the posterior scale, of the reproductive caste.

Only three species of Rhinotermitidae have been found in Trinidad. Each has been collected so frequently that further species, if any occur, are probably rare or restricted in habitat. In British Guiana Emerson (1925) records only two species of *Heterotermes*, one of *Coptotermes*, but no less than six of *Rhinotermes*.

Heterotermes.

Heterotermes tenuis (Hagen), the most ubiquitous and one of the most destructive termites in Trinidad, has been recorded from many parts of South and Central America, the West Indies and, presumably by introduction, in St. Helena. Emerson (1925), however, states that more than one species may be included in these records. In several Lesser Antillean islands—Tobago, Grenada, St. Vincent, Barbados and St. Thomas, Virgin Islands—I have collected soldiers indistinguishable from those of *H. tenuis* in Trinidad. In almost any part of Trinidad a few minutes search reveals the workers and soldiers of this species. It has been found in drift-wood a few feet from high tide-marks, and near the summit of the highest mountains. The underground nests are rarely found.

The pale yellow-brown night-flying alates have been found in colonies in May, June, July, October and November. In spite of the great abundance of this termite everywhere, I have seen alates swarming on only one occasion, on 6th June, 1936 at 10 p.m.

Coptotermes.

Coptotermes testaceus (L), of which *C. marabitanas* (Hagen) is a synonym (Emerson, *in litt.*), is the only member of its genus collected in Trinidad or, so far as I know, in the West Indies. Emerson (1925) records it alone from British Guiana, though in Central America several species are known and one, *C. crassus* Snyder, was recently found by Light (1933) in Western Mexico. The only published record of *Coptotermes* in the West Indies appears to be that of Emerson (1925) in Trinidad, but I have found soldiers of *C. testaceus*

in Tobago and received others from Grenada, from Mr. C. G. Munro. Soldiers of *Coptotermes* sent to me by Mr. R. W. E. Tucker in Barbados appear to differ slightly from those of *C. testaceus* in Trinidad, but may prove to belong to the same species.

In spite of the great damage by *Coptotermes* to buildings and other structures, and even living trees, in many countries, I have found *C. testaceus* in only two houses in Trinidad. In forests it is not uncommon, especially in rather damp wood, in which its wide galleries, lined with cement-like material, are characteristic.

Only a few colonies with alates have been found, in June. The winged forms are black and fly by day. A great swarm was observed during the rainy afternoon of 11th July, 1936, near St. Augustine, and small numbers on many occasions in June, July and August.

Rhinotermes.

Rhinotermes longilabius Emerson is the only species known in Trinidad, which is surprising in view of Emerson's (1925)record of six species in British Guiana. The alates are easily recognised by the peculiar nose-like projection of the clypeus, in front of the head. The soldier caste is dimorphic; the minor soldiers have reduced mandibles and the labrum (upper lip) is produced into a long snout recalling that of *Nasutitermes* but differing in its forked tip; the major soldiers, which are less abundant than the minor, have large, curved, toothed mandibles and a shorter labrum.

In Trinidad this species has been found only in forests, in rather damp, rotting wood, and no case of damage to human structures has yet been noticed. Alates have been seen in galleries in the months of June and July. In July many pairs of dealates that had not yet begun to lay eggs have been found in crevices in rotten logs.

Family Termitidae.

The Termitidae, the largest, most highly evolved and varied of termite families, is characteristically tropical and abundantly represented in Trinidad. Few of the species here have thus far been found attacking sound wood of human structures, though in other countries many of the Termitidae are extremely destructive. The saddle-shaped pronotum of workers and soldiers, and the short anterior wing-scales of the reproductive caste, distinguish the Termitidae from other families in Trinidad.

Cornitermes.

Cornitermes (*Labiotermes*) *labralis* Holmgren is the largest termite known in Trinidad. The total length of winged forms is about $\frac{7}{8}$-inch. The soldiers are easily recognised by their round, light reddish-brown heads, about 1/10 inch wide. The nests, which are not uncommon in forests, are also the largest of termite structures found here. They are almost always built up the sides of tree-trunks, dead or alive, from the ground to a height of up to four feet and attain diameters of up to two feet. The material of which the nest is made is usually black and the walls of the large "cells" have characteristically reticulated surfaces. Alates have been found in nests in May, June and July.

Armitermes.

The genus *Armitermes* is of special interest because the soldiers, though nasute, have large, curved, toothed mandibles. A single species, *A. holmgreni* Snyder (*A. albidus* Emerson), has been found in Trinidad, where it is fairly common in forests. The nests are very dark, earthy structures, usually built on or around dead tree stumps, the decay of which may leave the nest in the form of a low mound, often concealed by dead leaves. Records of alates in nests have been made in May, June and July.

Obtusitermes.

An undescribed species of *Obtusitermes* was collected by Dr. A. E. Emerson at Port-of-Spain on 29th November, 1920 (No. 521).

Nasutitermes.

Nasutitermes may be called the dominant genus of termites in Trinidad, since it probably exceeds all others in numbers both of species and individuals. As restricted in the system of nomenclature adopted by Emerson, it includes four known species in Trinidad and probably at least as many more undetermined or yet to be found. The soldiers of these and related nasute termites have reduced mandibles and are adapted for chemical warfare. The head is drawn out in front into a pointed snout or nozzle, with a pore at its end from which a defensive fluid is ejected. The best known species here make conspicuous "carton" or "niggerhead" nests high up on the trunks and branches of trees. One or more species are probably of considerable economic importance in Trinidad, though in comparison with other species they have thus far been found very seldom in buildings that are constantly occupied. This is due largely, but probably by no means entirely, to the conspicuous nature of the nests and of the covered passages leading to wood.

Nasutitermes costalis (Holmgren), (Figs. 3-4), is the commonest member of the genus in Trinidad and in numbers of individuals possibly the most abundant of all termites here, being widespread throughout the island. It is also widely distributed in South and Central America and in the West Indies, though Emerson (1925) remarks that many of the published records need verification. Most of the familiar "niggerhead" nests in Trinidad are of this species. They are readily distinguished from the equally common mud nests of *Microcerotermes arboreus* by the earthy appearance of the latter. The alates of *N. costalis* are almost entirely dark in colour and fly by day.

TRINIDAD TERMITES.

Fig. 1.

Fig. 2.

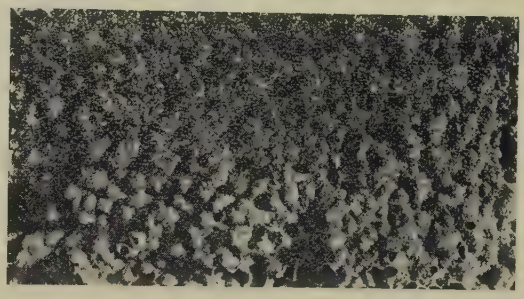

Fig. 3.

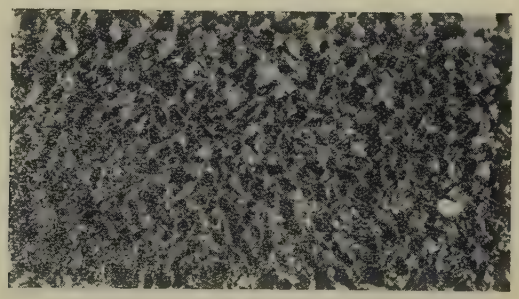

Fig. 4.

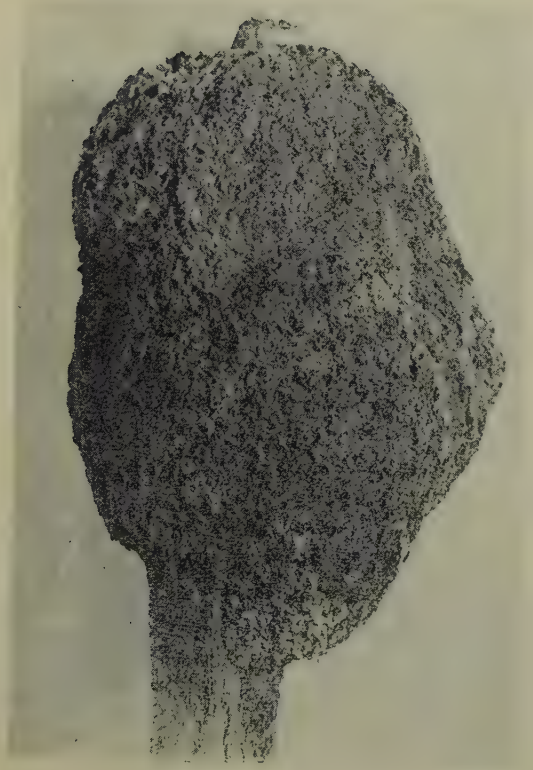

Fig. 5.

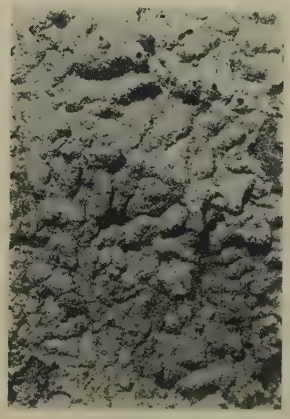

Fig. 6.

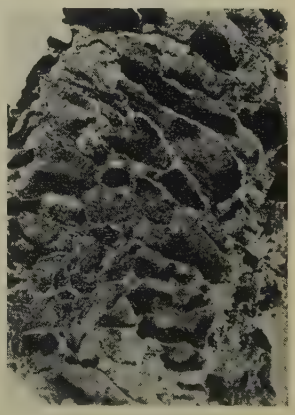

Fig. 7.

FIG. 1.—*Nasutitermes ephratae* (Holmgren), nest, × 0.3. FIG. 2.—*Nasutitermes* sp., Aripo Savannah, nest, × 0.1. Fig. 3.—*Nasutitermes costalis* (Holmgren), surface of nest, × 0.8. FIG. 4.—*Nasutitermes costalis* (Holmgren), internal structure of nest, × 0.8. FIG. 5.—*Microcerotermes arboreus* Emerson, nest, × 0.3. FIG. 6.—*Microcerotermes arboreus* Emerson, surface of nest, × 0.9. FIG. 7.—*Microcerotermes arboreus* Emerson, internal structure of nest, × 0.9.

TRINIDAD TERMITES.

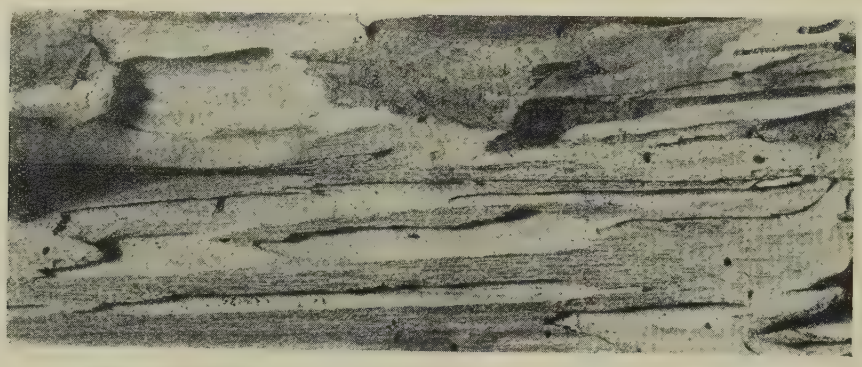

Fig. 8.

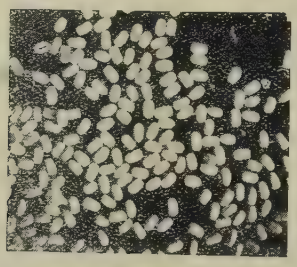

Fig. 9.

Fig. 10.

Fig. 11.

FIG. 8.—*Cryptotermes brevis* (Walker), galleries in wood, × 0.6. FIG. 9.—*Cryptotermes brevis* (Walker), faecal pellets, × 2.6. FIG. 10.—*Coptotermes testaceus* (L.), galleries filled with cement-like material, × 0.5. FIG. 11.—*Heterotermes tenuis* (Hagen), galleries lined with cement-like material, × 1.0.

Nasutitermes ephratae (Holmgren) (fig. 1), and *N. guayanae* (Holmgren) are much less common than *N. costalis*. The nests of all three species are somewhat similar in form and location. The surface of those of *N. guayanae* resembles that of *N. costalis*, but the nests of *N. ephratae* thus far examined in Trinidad have a relatively smooth surface, in the form of a thin, fragile pellicle. The soldiers of *N. costalis* and *N. ephratae* are very similar, those of *N. guayanae* considerably larger.

The mound nests (fig. 2) characteristic of the Aripo, Piarco and Mausica Savannahs, and probably on similar grasslands, are built by a species of *Nasutitermes* not yet identified. They are the only true termite mounds that I have found in Trinidad. Most of them are of rather regular form, conical but round on top, with a circular base up to 1½ feet in diameter, and a height of up to two feet.

Subulitermes.

Four species of *Subulitermes*—*S. parvellus* (Silvestri), *S. snyderi* Emerson and two undescribed species—were collected in Trinidad by Dr. Emerson. I have numerous collections of these small termites, the soldiers of which are nasute and without functional mandibles, but I have not yet attempted to study them systematically. At least one of them is very abundant in damp, rotting wood, and numerous nests, in the form of very low mounds of earth, have been found. Swarming alates of this species have been observed emerging from the ground on rainy days.

Anoplotermes.

Anoplotermes is the only genus of termite known to lack the soldier caste. For identification of species it is therefore necessary to obtain the reproductive forms and because of this, and also of the necessity for especially careful identification, I have as yet paid little attention to this genus in Trinidad. *A. brevipilus* Emerson, described from British Guiana, was collected by Dr. Emerson not far from Sangre Grande, Trinidad, 18th August, 1924. I have not yet attempted to discover how many species I have collected here nor to study their habits.

Crepititermes.

Crepititermes verruculosus Emerson, described as *Mirotermes* (*Crepititermes*) *verruculosus* from British Guiana, has been taken only a few times in Trinidad. Alates were found in June, 1936, in a low, inconspicuous earthy nest, some ten inches in diameter and about four inches high. This is the smallest member of the group of termites with long, slender, snapping mandibles thus far found in Trinidad.

Termes.

Termes hispaniolae (Banks)—the correct name, according to Dr. A. E. Emerson (*in litt.*), for the species described as *Mirotermes hispaniolae* Banks—is the commonest of the termites with long, snapping mandibles in Trinidad. It occurs very widely, in many types of habitat. Nests have been found both in and around dead stumps and logs, usually built irregularly and composed of characteristic, brick-red material. Alates have been found in May, June and July.

Cavitermes.

Cavitermes tuberosus Emerson—described from British Guiana as *Mirotermes* (*Cavitermes*) *tuberosus*—has been found only a few times in Trinidad. It is among the most interesting species. The snapping mandibles of the soldier resemble those of *Termes hispaniolae*, but the head is grotesquely deformed by a wide depression in the middle of the upper surface, and by a sharp ridge, pointed at the sides and in the middle, projecting from the front of the head. Alates have been found only once in Trinidad, in June, 1935, in a flat-topped mound, about 12 inches high and 15 inches in diameter.

Neocapritermes.

Neocapritermes angusticeps Emerson, described from British Guiana and the only member of its genus known in Trinidad, is not uncommon in forests of many kinds. The soldiers are easily recognised by their large parallel-sided heads and large, black, twisted, assymetrical snapping mandibles. Alates have been found on only a few occasions, in galleries in dead tree-trunks, in June and July.

Microcerotermes.

Microcerotermes arboreus Emerson is the common builder of earth or mud nests on tree-trunks, fence-posts, &c., in almost all parts of Trinidad. The nests are usually irregular, more or less elongated vertically and reach about two feet in length and one foot in diameter. The covered passages, except where widened near the nest, do not exceed ⅛-inch in external diameter, much less than in *Nasutitermes costalis*. In spite of the great abundance and wide distribution of *M. arboreus* in Trinidad, I have seldom found it damaging houses. It is, however, among the first termites to enter dead stumps and logs and it is probably one of the most injurious species to fence-posts, &c. When found in wood away from the nest it can be distinguished by the slender, curved mandibles of the soldier, arising near the middle of the front of the head, not laterally as in *Heterotermes*, and by the small, dark heads of the workers. The alates are small, delicate, darkly pigmented, and fly by day.

A small colony of a second species of *Microcerotermes*, possibly undescribed, was collected by the writer (No. 1200, 4th June, 1936) at about 2,000 feet in the rain-forest of the Northern Range. The nest, about 3½ inches in diameter, was built of reddish material on the top of a small tree-stump, about 12 inches from the ground.

Species.	Family.	Habit.	Runways.	Galleries in wood.	Soldier.
Heterotermes tenuis	Rhino-termitidae	Subterranean, nesting in ground	Narrow tubes, seldom conspicuous	Narrow, lined with cement-like material	Head yellow, elongated, parallel-sided ; slender mandibles
Cryptotermes brevis	Kalotermitidae	Dry-wood termite living only within wood	None	Empty, except for faecal pellets	Few in number ; head dark, square in front
Coptotermes testaceus	Rhino-termitidae	Subterranean, nesting in ground	Irregular passages often concealed	Wide, containing much cement-like material	Head yellow, rounded, emitting milky fluid
Microcerotermes arboreus	Termitidae	Mud nest, arboreal ; partially ground-dwelling	Narrow tubes, but often conspicuous	Empty, walls discoloured	Superficially like *Heterotermes* (workers with small, dark heads)
Nasutitermes costalis	Termitidae	Carton nest, arboreal ; partially ground-dwelling	Conspicuous tubes of dark material	Empty, walls discoloured	Head dark, pointed ; mandibles reduced

V.—Termite Damage.

The following pages are based on a preliminary survey of buildings, especially in and near St. Augustine and in Port-of-Spain, the capital of Trinidad. Many of the conclusions reached are tentative.

In the table above the species are arranged approximately and tentatively in order of their destructiveness in Trinidad, with special reference to buildings. The first two, *Cryptotermes brevis* and *Heterotermes tenuis*, appear greatly to exceed all others in importance, having been found responsible, together, for over 90 per cent. of the termite damage thus far investigated. Attention should be drawn here to the importance of distinguishing between the dry-wood termites, of the family Kalotermitidae, and the termites of other families, as shown in the table and described in succeeding pages.

The above table shows that the recognition of the species of termite responsible for most damage in buildings is fairly simple, even without a study of the termites themselves. If the galleries are empty save for small, round, hard pellets, accumulated here and there and often extruded for the tunnels, the work is almost certainly that of *Cryptotermes brevis* (figs. 8-9). Most injury to movable furniture, with which ultimate contact with the ground could not be maintained, is caused by the same species. If a cement-like material is found in the galleries, subterranean termites are involved, in most cases *Heterotermes tenuis* (fig. 11) and less commonly *Coptotermes testaceus* (fig. 10). The work of these species may be distinguished by the relatively narrow galleries, usually not exceeding $\frac{1}{2}$-inch in width, and the friable cement-like material lining them, of *Heterotermes*, and the wide galleries, often filled by large masses of hard material, of *Coptotermes*. If neither pellets nor large amounts of foreign material are found in the galleries, the damage is probably caused by *Nasutitermes* or by *Microcerotermes*.

If termites are present in the damaged wood, the principal species are easily recognised. Soldiers of *Coptotermes* are very abundant and when irritated emit a drop of milky fluid in front of the head, which is oval, tapering in front. Those of *Heterotermes* are less numerous ; their heads are elongated, with sides parallel ; no visible fluid is emitted. Both termites have slender, slightly curved mandibles. The soldiers of *Cryptotermes* have dark brown or black heads, square in front, with inconspicuous jaws ; they are not numerous in the galleries and often difficult to find without much cutting. The " workers " (strictly nymphs of the reproductive caste) are grub-like in form and move slowly. Soldiers of *Nasutitermes* have dark-brown heads, drawn out to a pointed snout, and inconspicuous jaws ; they occur very abundantly and move very rapidly when disturbed. Soldiers of *Microcerotermes* resemble superficially those of *Heterotermes*, but the small, dark heads of workers of *Microcerotermes* are distinctive.

The covered passages of the principal termites invading houses from the outside can in most cases be recognised specifically. Those of *Heterotermes* are usually very narrow tubes, of uniform width, not exceeding $\frac{1}{4}$-inch in external diameter. Those of *Coptotermes* are less regular, often losing their tubular form and the surface is usually more rough than in the case of *Heterotermes*. *Nasutitermes costalis* builds regular

tubes, in external diameter up to ½-inch, of rather coarse particles of brown or black material. The passages of *Microcerotermes arboreus* resemble those of *Heterotermes*.

Dry-wood Termites.

Dry-wood termites are exceedingly abundant in buildings in Trinidad, both in structural wood and in furniture. Probably almost all houses more than a few years old are infested to some extent. Only two species, both in the genus *Cryptotermes*, have thus far been found in buildings and damage by others, if any, is probably of relatively little importance. *Cryptotermes brevis* has been found much more frequently than the other injurious member of the genus, which has not yet been identified specifically. The following notes refer to *C. brevis* but will probably prove to be applicable to both species, which are similar in superficial appearance and probably in most of their habits.

As in the case of all dry-wood termites, infestation begins with the entry of a single pair, male and female, immediately after the swarming flight and shedding of the wings. In Trinidad most attacks by *Cryptotermes brevis* probably begin in June and July. Almost any small crevice, crack or other surface defect may be chosen for entry to the wood. The early multiplication of the termites is extremely slow. A pair of *C. brevis* under observation in captivity since June, 1936, laid about ten eggs within the first two months and none within the next six months. This is probably normal. The consumption of wood is therefore so slow that no damage may be visible years after infestation began. The first sign of the presence of the termites is usually the appearance of faecal pellets extruded from the galleries. The injury may not be serious even after the colony has attained large size. It is not uncommon to find a chair with thousands of individuals of *C. brevis*, in galleries reaching every part of the wood, and yet almost free from blemish and capable of use.

The only effective preventive measure against dry-wood termites under present conditions in Trinidad is the use of wood that is resistant naturally or by treatment. The entry of initial pairs may be prevented to some extent by a continuous coat of paint, free from defects. Screened houses are of course partially protected from flying termites, though they may crawl through openings not used by mosquitoes. Some of the direct measures mentioned on page 149 are of some use against dry-wood termites, especially in the case of small colonies.

Subterranean Termites.

These termites have underground nests, which are usually difficult to find, and the wood on which they feed is reached by means of extensive tunnels. Invasion of buildings therefore occurs from the ground, with which communication must be maintained, not only to the nest but also to water in the soil. Isolation of these termites from the ground results in their early death, unless they can survive on exceptional sources of water, such as a leaking pipe. Unfortunately subterranean termites can attack wood that is not in contact with the ground, by means of long tubular passages or runways built over impenetrable material such as stone, concrete or metal pipes. In search of wood they can also pass through extremely narrow cracks or other defects in building materials. Damage in buildings is not limited to wood, since books, papers, and other articles resting on shelves or floors are often invaded. Furniture that is frequently moved is of course immune from attack.

In almost all of the buildings thus far found to harbour subterranean termites in Trinidad, the species responsible has been *Heterotermes tenuis*. *Coptotermes testaceus* has yet been found in only two buildings. Damage by *Nasutitermes* and *Microcerotermes*, which lead a partially subterranean life, has not yet been noted except in the case of very old buildings, following on damage by other termites or other agents of decay, and in the case of buildings of very poor construction.

Injury to telegraph-poles, fences, wooden bridges, &c., has not been investigated except by casual observation. *Heterotermes* is probably the cause of most damage to these structures in Trinidad, but species of *Coptotermes*, *Nasutitermes*, and *Microcerotermes*, as well as some of the dry-wood termites, are probably of considerable importance.

Heterotermes tenuis, as already mentioned, is the most ubiquitous termite in Trinidad, and it is probably responsible for more damage than any other species. Its means of entering buildings are usually less noticeable than those of other ground-dwelling termites, and the problem of its control more difficult. Most of the subsequent notes on subterranean termites apply especially to this species.

The status of *Coptotermes testaceus*, as thus far investigated, is very surprising. As previously mentioned, it is common in forests, but I have yet found it damaging only two houses in Trinidad. One of these, a small wooden house in the village of Laventille, near the edge of the Caroni Swamp, had been very seriously damaged, wooden pillars six inches square in section having been hollowed out and filled with masses of the cement-like material characteristic of the genus. In the other case, a house near Mayaro Beach, the termites were present only in palings round the base of the house. During a short visit to Tobago in 1936, one of the two or three houses I examined was infested by this species. From Grenada I have received specimens found damaging lumber and from Barbados specimens of *C. testaceus* or a related species, from buildings. Emerson (1925) found it doing considerable damage to buildings in Georgetown, British Guiana. In very many tropical countries *Coptotermes* is one of the most destructive of all termites. Further investigation may show that it is more abundant in houses in Trinidad than appears at present.

VI.—Control of Termites.

Termites of all kinds are more delicate and easily killed when exposed than almost any other insects. Protected in their galleries, however, they are so difficult to kill that direct methods against them are of little use. The control of termite damage is therefore largely a matter of prevention, of which there are two main methods: termite-proof construction of buildings, against subterranean species, and the use of wood that is resistant, either naturally or after chemical treatment, against all kinds of termites. Both methods can be used in Trinidad as elsewhere, and in certain cases more simply than in countries where the raising of buildings high above the ground is little practised.

The brief suggestions made in succeeding pages are based on observations on the habits of termites in Trinidad, but not on any personal research in methods of control. In the extensive literature the works of the following are especially recommended: Kofoid, Light and others (1934), Snyder (1935), Light, Randall and White (1930) and Jepson (1929).

Termite-proof Construction.

The general principle of construction to prevent the invasion of buildings by subterranean termites is simply insulation of susceptible wood from the ground. The ability of termites to enter by extremely small spaces and to build covered passages over impenetrable material, however, makes this insulation very difficult to attain in buildings that are not raised on pillars clear off the ground. The technical details involved are beyond the scope of this brief report, and reference must merely be made to the papers mentioned above, in which full directions, adaptable to most conditions, are to be found.

Attention should be drawn to the fact that the slightest defect may result in extensive damage, and that elaborate termite-proof construction should not be attempted unless perfection is likely to be attained.

Many houses in Trinidad built on pillars of concrete and wood suffer severe damage which could be prevented by attention to a few simple details. The case of a house recently examined may be described as typical. Though designed for immunity to subterranean termites, having a continuous concrete foundation and being elevated on concrete pillars about two feet high, it had been so extensively damaged by *Heterotermes tenuis* that a great part of the walls, floors and ceilings had to be replaced. Examination immediately revealed the mode of entry, at about six points, through minute fissures in the concrete foundation at the base of the pillars. These were L shaped in section and in the angles the termites had built their runways, matching the concrete in colour and thus indiscernible except to one searching for them. In this case control is simply a matter of inspection and repair of slight defects.

The problem is greatly simplified if high pillars are used, a type of construction which has many other advantages, reducing invasion by ants as well as termites, increasing circulation of air, and providing useful space below the house. Inspection for termite runways becomes a simple matter. The only precautions necessary are (1) the elimination of all susceptible wood connecting the house and the ground; (2) absence of spaces within pillars and other structures, by which termites may pass unobserved; (3) absence of concealed surfaces over which runways can escape detection. The form of pillars, steps, &c., should be as simple as possible, so that plain, smooth surfaces may be everywhere freely exposed. Metal pipes, for example, should not stand close to concrete, the concealed surfaces between them providing an easy hidden path for subterranean termites. Special care should be devoted to outside stairways.

The use of concrete foundations is of little value unless cracks and other defects can be avoided. For houses on tall pillars attention to structures between the house and ground level is much more profitable.

The judicious use of small quantities of resistant wood at vulnerable points, and of concrete in which, for example, pillars of susceptible wood may be set, may make it possible to render certain buildings termite-proof at small expense.

Naturally Resistant Woods.

The use of timber naturally immune to termite attack is, when practicable, the most satisfactory preventive measure, because it is effective against all kinds of termites and eliminates the need of all other precautions. Unfortunately, many of the least expensive timbers are highly susceptible to attack, and there is urgent need for development in the production and use of resistant woods. Fortunately, the Forest Department of Trinidad is actively engaged in this field, an extensive series of durability trials being now conducted by Mr. C. Swabey, the Assistant Conservator of Forests. I am indebted to him, as well as to Mr. R. L. Brooks, Conservator of Forests, for the information on which the following brief notes are based.

Among the most widely used of local timbers the following are known to be highly resistant to termites: Balata (*Mimusops balata* var. *cruegeri* Pierre), Black Fiddlewood (*Vitex divaricata* Sw.), Cedar (*Cedrela mexicana* Roem.), Guatecare (*Eschweilera sub-glandulosa* (Steud.) Miers.) and Yellow Poui (*Tabebuia serratifolia* Nichols.). Mahoe (*Sterculia caribaea* R. Br.) and Toporite (*Hernandia sonora* L.), which are extensively used, are susceptible to attack. The foreign timbers imported in greatest quantity in Trinidad, Pitch Pine (*Pinus palustris* Miller) and Douglas Fir (*Pseudotsuga douglasii* Carrière), are unfortunately highly susceptible. It should be noted that sapwood of almost all kinds of timber is liable to attack.

Chemical Treatment of Wood.

Partial immunity to termites may be attained by superficial painting with many preservatives, of which coal-tar creosote is still one of the most widely used. For resistance over prolonged periods deep penetration of the preservative is necessary and this can be attained only by special methods, usually under pressure. An extensive account of these is given in "Termites and Termite Control" (Kofoid and others, 1934) and in simpler form in Snyder's recent book (1935). Investigations by the Forest Department of Trinidad are in progress.

Destruction of Termites by Direct Methods.

Though of little value as compared to methods of prevention, the following means of killing termites are worth brief mention here.

Fumigation of small articles of furniture may be used against dry-wood termites, in any kind of air-tight container, such as a metal trunk or bin. Carbon bisulphide—widely used locally, under the name "Calypso", for destroying nests of Parasol Ants—is effective. A simple device for treating woodwork in buildings has recently been described by Uichanco (1932). A wad of cotton soaked in carbon bisulphide is placed over an opening to the galleries of termites or other borers, and covered by a double sheet of wet newspaper adhering closely to the wood. The fumes are thus allowed to act over-night or longer and the application repeated if necessary.

Poisonous dusts, especially Paris Green, have somewhat recently been employed, especially against dry-wood termites and notably against termites in tea-bushes in Ceylon. The dust is blown into an opening to the galleries and because of the termites' habit of consuming dead members of the colony, the poison may be widely disseminated, ultimately destroying the entire colony. A limited use of this method could probably be made against dry-wood termites in Trinidad. Attention should be directed, however, to the recent recommendation of the Termite Investigation Committee in California, against the use of arsenicals in buildings. This is because of the peculiar ability of certain fungi which may occur in termite galleries to absorb arsenic and later to emit it in the form of diethylarsine, a highly toxic gas. It seems unlikely that this danger will be serious in places like Trinidad, where buildings are very freely ventilated.

Attempts to destroy the nests of subterranean termites such as *Heterotermes tenuis* are usually futile. Building sites, however, should be freed from termites before construction is begun, and temporary reduction of damage already in progress may sometimes be attained by treatment of the ground around the building. For soil treatment Snyder (1935) recommends a ten per cent. solution of sodium arsenite, lead arsenate at the rate of five lb. per 1,000 sq. ft., a mixture of one part coal-tar creosote to three parts kerosene, and carbon bisulphide emulsion.

Exposed nests of *Nasutitermes* and *Microcerotermes*, as well as their conspicuous runways, are easily removed. In some cases it is advisable to apply a repellent such as creosote to prevent rebuilding of runways.

Summary.

A survey of the termite fauna of Trinidad is well advanced as regards collections. A list of those thus far determined, together with those collected by Dr. A. E. Emerson, includes over 30 species in about 20 genera, but probably represents not much more than half of the species present.

Brief notes on the occurrence, habits, and probable economic status of the principal genera and species are given. The commonest builders of arboreal nests are *Microcerotermes arboreus* Emerson and *Nasutitermes costalis* (Holmgren). No builders of large mounds are known. The commonest subterranean termite is *Heterotermes tenuis* (Hagen).

A preliminary survey of small extent indicates that most damage in buildings is caused by the dry-wood termite, *Cryptotermes brevis* (Walker), and by the subterranean *Heterotermes tenuis*, which is probably the species most destructive to wood used outside buildings. *Coptotermes testaceus* (L.), though common outside, has yet been found damaging few houses in Trinidad. Other termites have rarely been found attacking sound wood in buildings.

Control measures applicable to local conditions are briefly outlined. The most important point is that extensive damage by subterranean termites, to buildings elevated on pillars of concrete and wood, could be largely avoided by attention to a few simple details in construction, designed to prevent invasion by termite runways leading from the ground.

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RECENT INVESTIGATIONS ON SUGAR-CANE AND SUGAR-CANE SOILS IN ANTIGUA.

II.—MANURIAL EXPERIMENTS REAPED IN 1936.

By P. E. Turner, F. H. S. Warneford and C. F. Charter.

Introduction.

A scheme of field experiments was inaugurated in Antigua in 1933 under the auspices of the Sugar-Cane Investigation Committee of the island. The design of the scheme is such as to make thorough and systematic enquiry into the more fundamental practices in use on the sugar estates of Antigua and to compare their merits with alternative practices which have proved successful in other sugar-growing countries, due regard being paid to local conditions.

Detailed descriptions of the Scheme have been published elsewhere (1). As the scheme develops it is intended to include experiments grouped under the following headings :—

Cultural.
Drainage.
Preparation of the soil for planting.
Cultural treatment after planting.
Cultural treatment of ratoon canes.

Conservation of soil moisture.
Mulching with megasse, trash, &c.

Varieties.
Comparisons of varieties.
Time of planting.
Distance of spacing.

Manuring.
Pen manure.
Filter-press mud and molasses.
Inorganic nitrogen, phosphate and potash on penmanured and unpenmanured soils.

Soil amelioration.
Sulphur and pen manure.

Grassland.
Cultural and manurial treatment.

A preliminary series of experiments laid down under the scheme was harvested in 1935. The information to which it gave rise has been summarised in earlier issues of this *Journal* (2).

A second series of experiments was reaped in 1936. An account is given in this paper of the manurial experiments which were included in this series. The results of the cultural, mulching, varietal and grassland trials will be discussed in later papers.

The size of the individual plots used in the experiments was 1/20 to 1/30 acre unless stated otherwise. With few exceptions all plots in each experiment were surrounded by border rows of cane.

Classification of the Soil types of Antigua.

In a previous publication (2) the soils of the sugar-cane areas were divided into four main groups, determined by their geological and physico-chemical characters :—

(1) soils derived from the Antigua and Seaforth limestone formations,

(2) soils derived from the siliceous clays of the tuff or limestone regions,

(3) sandy soils of volcanic origin derived from basement rocks or lower fertile gritty-tuffs, and

(4) alluvial soils derived from non-calcareous clay-tuffs and sandy soils.

During the past year the soils have been further intensively studied and it has been found necessary to subdivide each of the main groups into types according to the particular nature of the soil profile. Each type has been given a two-part name, the first part being determined by the locality or estate in which the profile is typically developed, the second part being descriptive of the mechanical composition of the surface layer (*i.e.*, the layer which is cultivated and to which the root system of sugar cane is largely confined). The new types have been accepted as standard for the purpose of these investigations. Their distribution among the four main groups* is set out below.

Antigua and Seaforth limestone formations.
Wetherell's clay.
Fitches clay.
Delap's clay.

Siliceous clays of the tuff or limestone regions.
Gunthorpe's clay.
Tomlinson's clay.
Elliot's sandy clay.
Otto's clay.

Basement rocks or lower fertile gritty tuffs.
Otto's clay.
St. Clair bouldery clay.
Gordon clay.

Alluvial.
Blubber Valley sandy loam.
Leonard's loam.
Bendall's clay.
York's clay.

A full description of these soil types will be published elsewhere.

* Unpublished communication by C. F. Charter.

Experiments with Organic Manures.

Pen Manure.

Method of Application.

Two general methods of applying pen manure are available. In one the manure is buried in the soil before planting. This method allows time for the manure to decompose in part before it is required by the plant, but losses of nutrients through leaching may occur during the interval. In the other the manure is applied after planting.

In the cattle-ploughed areas of Antigua (and St. Kitts) the former method is in general use. The pen manure is ranged along the rows of stubble and covered with trash. The lanes of bare soil between the rows are then ploughed and the furrow slices are turned on the pen manure and trash which are buried in the banks thus formed.† When pen manure is applied after planting it is usual to place the manure in the furrows shortly before the banks are broken and to cover it with soil during this operation.

The relative effect on yield of plant canes of the two methods of application has been compared under Antiguan conditions. To minimise disturbing factors the experimental area was gyrotilled and furrowed by hand. In one series of plots the pen manure was buried under the banks at the time of their preparation (some two months before planting). In the other series it was scattered around the stools in the furrows prior to breaking the banks (some four months after planting). The size of dressing of pen manure to all plots was ten tons to the acre. The manure was of average quality. The layout of the experiment was in the form of five randomised blocks with two replicates of each treatment in each block.

The mean yields of plant canes for the two series of plots are recorded in Table I.

Table I.—Relative effect on yield of plant canes of method of application of pen manure.

Soil type: Gunthorpe's clay (4.5 per cent. $CaCO_3$).
Estate: Fitches Creek. *Variety*: B.H. 10(12).
Penmanured: 17/12/34 (under banks), 15/6/36 (in furrows).
Planted: 20/2/35. *Reaped*: 21/4/36.
Rainfall (14 months): 43 inches.
Layout: Randomised blocks.

Method of application of pen manure.	Yield of plants* tons per acre.
Under the banks	30.57
In the furrows	30.06

* Mean values for ten replicates.

In this experiment method of application of the pen manure had no appreciable effect on the yield of plant canes.

† Variants of this method exist, *e.g.*, the pen manure may be deposited in heaps at intervals in the furrows and buried under the cross-bars.

Immediate and Residual Effects of Pen Manure on Yield.

Optimum Size of Dressing.

Seven experiments with pen manure have now been harvested, three as plant canes and first ratoons and four as plant canes. Four of these experiments were laid down on areas of Fitches clay, two on areas of Gunthorpe's clay and one on an area of Otto's clay. The data obtained are of general interest for they disprove the prevalent belief that reliance can be placed on dressings of pen manure to give satisfactory gains in yield of plant canes.

In the account which follows the term 'quality' as applied to pen manure, is used in the main to denote the ratio of animal droppings to trash and the degree of decomposition of the trash.

Experiments on Fitches clay.

The experiments at Gaynors and Yeamans Estates (2) have been reaped for the second time. The yield data are set out in Tables II and III.

Table II.—Immediate and residual effects of size of dressing of pen manure of good quality on yield.

Soil type: Fitches clay, deep phase (50 per cent. $CaCO_3$).
Estate: Gaynors. *Variety*: Ba.11569.
Planted: 8/2/34. *Penmanured*: 5/7/34.
Reaped: 16/4/35 (as plants), 13/4/36 as first ratoons.
Rainfall: 35 inches as plants (14¼ months), 39 inches as first ratoons (12 months).
Layout: Three 4 × 4 Latin squares.

Yields are expressed as tons cane per acre.

Pen manure per acre (1934).	Plants (1935).		1st Ratoons (1936).		Total gain (to date).
	Yield.	Gain.	Yield.	Gain.	
Nil.	26.56	—	26.16	—	—
12 tons	32.65	6.09	29.90	3.74	9.83
24 tons	34.62	8.06	32.71	6.55	14.61

The area on which this experiment was laid down in the past has been regularly and generously dressed with pen manure at each replanting. The pen manure used in the experiment consisted largely of animal droppings and was well above the average in quality (2). It was applied in the furrows five months after planting.

The immediate gains in yield of plant canes and the residual gains in yield of first ratoons might be due to chance far less than once in 100 times. They are larger than those gains to which dressings of pen manure of average quality give rise (cf., Tables III and IV).

A curve of diminishing returns is obtained when gain in yield is plotted against size of dressing of manure. The total gain, to date, from the dressing of 24 tons is only 50 per cent. larger than from 12 tons.

Sulphate of ammonia was applied to the plant canes on one series of plots in this experiment. No immediate or residual gain in yield was found to result from its use. The effect of sulphate of ammonia on yield of cane on calcareous soils is discussed later in this paper.

Table III.—Immediate and residual effects of pen manure of good quality on yield.

Soil type: Fitches clay, deep phase (18 per cent. $CaCO_3$).
Estate: Yeamans. *Variety*: Ba. 11569.
Planted: 2/3/34. *Penmanured*: 10/7/34.
Reaped: 5/4/35 (as plants), 8/4/36 as first ratoons.
Rainfall: 41 inches as plants (13 months), 39 inches as first ratoons (12 months).
Layout: Latin squares.

Yields* are expressed as tons cane per acre.

Pen manure per acre (1934).	Plants (1935).		1st Ratoon. (1936).		Total gain (to date).
	Yield.	Gain.	Yield.	Gain.	
Nil	31.76	—	22.51	—	—
10 tons	35.57	3.81	26.16	3.65	7.46

* Mean values for ten replicates.

This area has been regularly and generously dressed with pen manure at each replanting. The manure used in the experiment was average in quality (2). It was placed in the furrows, between the stools, and covered with earth some four months after planting.

The gains in yield of 3.81 tons of plant canes and 3.65 tons of first ratoons might both be due to chance less than once in 100 times.

Two experiments with pen manure on Fitches clay, laid down at Pares-and-Cochranes and Thibous Estates, have been reaped for the first time. The yield data are summarised in Tables IV and V.

Table IV.—Immediate effects on yield of size of dressing of pen manure of average quality.

Soil type: Fitches clay, deep phase (13 per cent. $CaCO_3$).
Estate: Pares and Cochranes.
Variety: B.H. 10 (12). *Penmanured*: 22/12/34.
Planted: 4/1/35. *Reaped*: 27/2/36.
Rainfall (13¾ months): 38 inches.
Layout: Two 5 × 5 Latin squares.

Pen Manure per acre (1934).	Yield of plant canes tons per acre (1936).	Gain tons per acre.
Nil	26.21	—
12 tons	29.35	3.14
24 tons	31.38	5.17
36 tons	31.53	5.32

This area also has been regularly dressed with pen manure in the past. The manure used in the experiment was average in quality. It was applied in the furrows, and buried under the cross-bars, two weeks before plantings.

The gains in yield of plant canes might be due to chance less than once in 100 times. The rate of gain begins to diminish when the dressing exceeds 12 tons to the acre. The additional gain from the dressing in excess of 24 tons is very small.

The immediate gains in yield recorded in Tables III and IV are in close agreement with those obtained from dressings of pen manure of average quality in Trinidad.

Table V.—Immediate effect on yield of pen manure of average quality.

Soil type: Fitches clay, deep phase (45 per cent. $CaCO_3$).
Estate: Thibous.
Variety: Ba. 11569. *Penmanured*: 17/4/35.
Planted: 30/11/34. *Reaped*: 13/3/36.
Rainfall (15½ months): 47 inches.
Layout: Latin squares.

Pen manure per acre (1935).	Yield of plant canes* tons per acre (1936).	Gain tons per acre.
Nil	30.93	—
10 tons	31.22	0.29

* Mean values for ten replicates.

It is doubtful whether this area has been regularly penmanured in the past. A manure of average quality was used in the experiment. It was applied in the furrows some four and a half months after planting. The gain in yield of plant canes resulting from the dressing of ten tons of the manure is negligible.

Experiments on Gunthorpe's clay.

The yield data for the plant canes in two experiments with pen manure which have been harvested on this soil type are set out in Tables VI and VII.

Table VI.—Immediate effect of pen manure of good average quality on yield.

Soil type: Gunthorpe's clay (0.7 per cent. $CaCO_3$).
Estate: Gunthorpe's.
Variety: B.H. 10 (12). *Penmanured*: July, 1934.
Planted: 21/12/34. *Reaped*: 27/5/36.
Rainfall (17¼ months): 38 inches.
Layout: Latin squares.

Pen manure per acre (1934).	Yield of plant canes* tons per acre (1936).	Gain tons per acre.
Nil	16.00	—
20 tons	17.52	1.52

* Mean values for 24 replicates.

The layout of this experiment was in the form of three 4×4 Latin squares with two replicates of each treatment in each row and column. The pen manure, which was of good average quality, was applied under the banks some five months before planting.

On this low-yielding area† the gain in yield of plant canes resulting from a dressing of 20 tons of pen manure to the acre amounted to only 1.52 tons.

Table VII.—Immediate effect of pen manure of good quality on yield.

Soil type: Gunthorpe's clay (5.4 per cent. $CaCO_3$).
Estate: Fitches Creek.
Variety: B.H. 10 (12). *Penmanured*: 26/6/35.
Planted: 14/12/34. *Reaped*: 1/4/36.
Rainfall (15½ months): 45 inches.
Layout: Latin squares.

Pen manure per acre (1935).	Yield of plant canes* tons per acre (1936).	Gain tons per acre.
Nil	26.91	—
10 tons	27.52	0.61

* Mean values for ten replicates.

In this experiment the pen manure, which was of very good quality, was applied in the furrows around the stools some six and a half months after planting. The area was last penmanured in 1929.

The gain in yield resulting from the dressing of ten tons of the manure was less than one ton of plant canes to the acre. A manure of similar quality, applied approximately the same time after planting, gave rise to a large immediate gain in yield in one of the experiments on Fitches clay (Table II).

An experiment on Otto's clay.

One experiment on plant canes with pen manure has been reaped on this soil type (Table VIII).

Table VIII.—Immediate effects of size of dressing of pen manure of poor quality on yield.

Soil type: Otto's clay (0.4 per cent. $CaCO_3$).
Estate: Ottos.
Variety: B.H. 10 (12). *Penmanured*: 7/6/35.
Planted: 3/1/35. *Reaped*: 18/3/36.
Rainfall (14½ months): 54 inches.
Layout: Two 5 × 5 Latin squares.

Pen manure per acre (1935).	Yield of plant canes* tons per acre (1936).	Gain tons per acre.
Nil.	23.55	—
8 tons	23.85	0.30
16 tons	25.42	1.87

* Mean values for ten replicates.

† There is reliable field evidence to the effect that treatment with pen manure fails to give rise to satisfactory gains on certain low-yielding areas of Tomlinson's clay.

The pen manure, which was purchased from villages, was poor in quality and composed of dried-out material. It was applied in the furrows some five months after planting.

The gain in yield of plant canes resulting from the dressing of eight tons of the manure to the acre is negligible. The gain from the dressing of 16 tons is statistically significant, but small.

Summary and discussion.

The results so far obtained in the experiments on plant canes with pen manure are summarised in Table IX. In only three out of seven experiments has this manure given rise to satisfactory immediate gain in yield. In the remaining four the response was definitely unsatisfactory.

Provisional conclusions which may be drawn from the collected data with regard to factors determining the response in yield of plant canes to dressings of pen manure are outlined below.

(1) The success or failure of pen manure does not appear to depend on the variety of cane. Both satisfactory and unsatisfactory results are recorded for plants of the varieties Ba. 11569 and B.H. 10(12).

(2) The success or failure of pen manure does not appear to depend on the concentration of calcium carbonate in the topsoil. Satisfactory and unsatisfactory results are recorded for soils containing more than 40 per cent. calcium carbonate and unsatisfactory results for soils containing less than one per cent. calcium carbonate.

(3) Success or failure does not appear to depend primarily on the quality of the dressing. Manure of very good quality gave a satisfactory gain on Fitches clay but a small gain on Gunthorpe's clay.

(4) Success or failure to some extent may be dependent on soil type. Soil type alone however, is not the only important factor for the manure gave satisfactory gains in three experiments on Fitches clay but failed in one experiment on this soil type.

(5) The success or failure of pen manure appears to be dependent on the treatment of the soil in the past. The three experimental areas for which satisfactory gains are recorded are those which have been regularly manured at previous replantings.

(6) The success or failure of pen manure does not appear to be entirely determined by its time of application. Late applications on Fitches clay were successful in two experiments and unsuccessful in a third experiment. Early and late applications failed in experiments on Gunthorpe's clay. The relationship between time of application of the manure and response in yield of plant canes is probably dependent on the manurial history of the soil, for it would seem that satisfactory gains can result from late applications on regularly manured areas.

It has been found elsewhere (3, 4) that the nitrogen and potash, but not necessarily the phosphate, contained in pen manure become largely available to the crop of plant canes to which the

Table IX.—Summary of results of experiments on plant canes with pen manure reaped in 1935 and 1936.

Soil type.	$CaCO_3$ in topsoil (per cent.).	Previous treatment of experimental area.	Time of application of pen manure.	Quality* of pen manure.	Variety of cane.	Effect on yield of plant canes.
Fitches clay	50	Regularly penmanured	5 months after planting	Very good	Ba. 11569	Satisfactory
do.	18	do.	4 months after planting	Average	Ba. 11569	do.
do.	13	do.	2 weeks before planting	Average	B.H. 10(12)	do.
do.	45	Doubtful	4½ months after planting	Average	Ba. 11569	Not Satisfactory.
Gunthorpe's clay	0.7	Not regularly penmanured	5 months before planting	Good	B.H. 10(12)	do.
do.	5.4	do.	6½ months after planting	Very good	B.H. 10(12)	do.
Otto's clay	0.4	Doubtful	5 months after planting	Poor	B.H. 10(12)	do.

* The term quality is used in the main to denote ratio of animal droppings to trash and the degree of decomposition of the trash.

dressing is applied. The phosphate may not become extensively available until the ratoon stages of the crop. Later in this paper (Tables XXIII and XXIV) it is shown that plant canes on areas of Gunthorpe's and Fitches clays can respond normally to treatment with a complete inorganic manure provided that nitrogen, potash and water-soluble phosphate are applied sufficiently early in the life of the plant, but that on both soil types little or no response may result if the treatment is given late. Evidence has been accumulated to the effect that early dressings of nitrogen can fail to give the customary increase in yield of plant canes on calcareous soils unless available phosphate is applied at the same time. On the basis of these findings it is possible to provide a general explanation of the success or failure of plant canes to respond satisfactorily to treatment with pen manure in the experiments which have been described.

On areas which have been regularly manured in the past it is probable that a store of nitrogen, phosphate and potash has accumulated in the soil in a form immediately available to the root system of the young plant at the time of its appearance. In such case there is good reason to believe that later applications of a suitable manure, whether organic or inorganic in character, are capable of additional beneficial effect.

On areas which have not been regularly manured it is probable that the store of readily available nutrients in the soil is low. In these circumstances a dressing of pen manure to plant canes, even if applied before planting (*i.e.*, under the banks or cross-bars) cannot be relied on to give satisfactory immediate gain in yield, for decomposition of the manure is unlikely to take place rapidly enough to provide an adequate supply of available phosphate during the critical period in the early life of the crop.

Cost of Pen Manure.

Data are available which enable an estimate of the cost of pen manure in Antigua, under conditions of rigid economy.

Stock are kept for three reasons, for transport to the rail-head, for cultivation and for provision of manure. Mechanical means are available for transport and cultivation*.

It is not unreasonable to charge one-third of the expenditure on stock in the stable to the production of pen manure. At this rate the manure in the stable can be shown to cost $1.12 per ton. The labour charges for carting the manure and applying it in the field are $0.13 per ton. Wear and tear on the carts and the upkeep of stock during transportation, and incidental associated expenses, amount to $0.25 per ton. This brings the total cost of pen manure, applied in the field, to $1.50 per ton†. An identical figure was obtained in an estimate made in Trinidad in 1932 (5).

Penmanuring is therefore an expensive operation. A dressing to the acre of 12 tons (the optimum size according to the results of field experiments) costs $18.00. Much larger dressings than this are commonly applied in Antigua.

FILTER-PRESS MUD.

Immediate and Residual Effects of Filter-Press Mud on Yield.

Optimum Size of Dressing, &c.

The experiments with filter-press mud have the following ultimate aims:—

(1) to determine whether this waste product of the factory can be used to replace village manure, which is usually not only poor in quality but also expensive (1);

* Mechanical means of transport to the rail-head are being increasingly adopted in St. Kitts. Mechanical means of ploughing are widely used in Antigua.

† In England a ton of farmyard manure is valued at abour $2.40.

(2) to find the optimum dressing for maximum financial gain ; and
(3) to compare the manurial value of filter-press mud with that of pen manure.

Three experiments have now been reaped, one as plant canes and first ratoons, and two as plant canes. Two of the experiments were laid down on Fitches clay and one on Gunthorpe's clay.

An experiment on Fitches clay.

The experiment at Yeamans Estate (2) has been harvested a second time. The yield data are set out in Table X.

Table X.—Immediate and residual effects of size of dressing of filter-press mud on yield. Filter-press mud *v.* pen manure.

Soil type: Fitches clay, deep phase (18 per cent. $CaCO_3$).
Estate: Yeamans. *Variety*: Ba.11569.
Planted: 2/3/34. *Manured*: 10/7/34.
Reaped: 5/4/35 (as plants), 8/4/36 as first ratoons.
Rainfall: 41 inches as plants (13 months), 39 inches as first ratoons (12 months).
Layout: Two 5 × 5 Latin squares.

Yields are expressed as tons cane per acre.

Manurial treatment per acre (1934).	Plants (1935).		1st Ratoon. (1936).		Total gain (to date).
	Yield.	Gain.	Yield.	Gain.	
Nil	31.76	—	22.51	—	—
3 tons filter-press mud	35.73	3.97	24.41	1.90	5.87
6 tons filter-press mud	36.33	4.57	26.54	4.03	8.60
9 tons filter-press mud	37.12	5.36	28.07	5.56	10.92
10 tons pen manure	35.57	3.81	26.16	3.65	7.46

The area on which the experiment was laid down has been regularly penmanured in the past. The filter-press mud was applied in the furrows some four months after planting.

The immediate gains in yield of the plant canes and the residual gains in yield of the first ratoons, resulting from treatment with filter-press mud, might be due to chance less than once in 100 times. The total gain in yield diminishes rapidly in rate when the dressing exceeds three tons to the acre. The gain so far obtained from three tons of the mud is more than half as large as that given by nine tons.

The pen manure used in the experiment was average in quality. The gain in yield of plant canes from ten tons of pen manure was rather less than that from three tons of filter-press mud. The gain in yield of ratoon canes from this dressing of pen manure was almost equal to that from six tons of the mud. The proportionately larger residual effect of pen manure may be due to the potash which it contains. Little or no potash is present in filter-press mud. On the basis of total gain in yield of plant canes and first ratoons ten tons of pen manure were equivalent in value to about 5 tons of filter-press mud under the conditions of the experiment.

Experiments on Fitches clay and Gunthorpe's clay.

The data for plant canes obtained from corresponding experiments on another area of Fitches clay and on an area of Gunthorpe's clay are recorded in Table XI.

Table XI.—Immediate effect of size of dressing of filter-press mud on yield.

Soil type:	Fitches clay, deep phase. (45 per cent. $CaCO_3$).	Gunthorpe's clay. (0.7 per cent. ($CaCO_3$).
Estate:	Thibous.	Fitches Creek.
Variety:	Ba. 11569.	B.H. 10(12).
Planted:	30/11/34.	14/12/34.
Manured:	30/4/35.	26/6/35.
Reaped:	13/3/36.	1/4/36.
Rainfall:	47 inches (15½ months).	45 inches (15½ months).

Layout: Two 5 × 5 Latin squares at each site.

Manurial treatment per acre (1935).	Yield of plant canes (tons per acre).			
	Fitches clay.		Gunthorpe's clay.	
Nil	30.93		26.91	
3 tons filter-press mud	31.75		26.94	
6 tons filter-press mud	30.33	31.27	26.50	26.73
9 tons filter-press mud	31.74		26.76	
10 tons pen manure	31.22		27.52	

Neither experimental area has been regularly penmanured in the past. The dressings of filter-press mud were applied not earlier than five months after planting.

No gain in yield of plant canes resulted from treatment with filter-press mud or with pen manure in these experiments.

The pen manure used on the Fitches clay was average in quality. That used on the Gunthorpe's clay was above the average.

Summary.

Treatment with filter-press mud has been found to give rise to satisfactory immediate gain in yield in one of three experiments. In all three experiments the mud was applied some considerable time after planting. The successful experiment alone was laid down on an area which has been regularly manured at previous replantings. The trend of the data for the experiments on filter-press mud is therefore in agreement with the results of the experiments on pen manure.

(*To be continued.*)

COTTON NOTES.

Three genes in a wild species of cotton. (*G. Armourianum* Kear.)

By Sydney Cross Harland.

(*Instituto Agronomico do Estado de Sao Paulo, Campinas, Brasil.*)

It is now known that the cottons of the American continent may be divided into two groups of species with 13 and 26 pairs of chromosomes respectively. One of the diploid species, (*G. Armourianum*, Kearney) was obtained through the kindness of Dr. T. H. Kearney in 1930 and has since been used for crossing experiments with other species of the Genus Gossypium. The first hybrids between New World cotton (*G. hirsutum*) and *G. Armourianum* were made by Mr. S. H. Evelyn in 1932 and the plants were later examined and described by Dr. A. Skovsted (1935). The latter found that the Armourianum plant used as ♂ parent was heterozygous both for pollen colour and for petal spot, since the F_1 could be divided into four classes as follows :—

Five with yellow pollen and petal spot present.
Five with yellow pollen and petal spot absent.
Five with cream pollen and petal spot present.
Four with cream pollen and petal spot absent.

After it was established that crosses could easily be made between *Armourianum* and New World cottons, a further series of experiments was begun in which the same *Armourianum* plant was crossed with a type of *barbadense* with three recessive characters, *viz.* cream corolla, cream pollen, and no petal spot. As the *Armourianum* parent had the characters yellow corolla, yellow pollen, and strong petal spot, it was hoped by repeated back-crossing to transfer the genes responsible for these three characters to *barbadense*, and subsequently to establish their identity or otherwise with the corresponding known genes controlling these characters in New World and Asiatic cotton respectively.

The F_1 was easily made and 23 plants were raised to the flowering stage. It was expected from Skovsted's work that the F_1 would segregate for P (yellow pollen) and S (petal spot). It was found, however, that all three characters segregated in the F_1 giving the following results :—

Corolla		Pollen.		Petal Spot.	
Yellow	Cream	Yellow	Cream	Present	Absent
11	12	13	10	12	11

It is clear that as the *barbadense* parent had been established to breed true to the triple recessive *yps*, the single *Armourianum* plant used as the ♂ parent in the cross, must have been heterozygous for three pairs of characters, *viz.* yellow or cream corolla, yellow or cream pollen, and petal spot or spotless.

The genes concerned may be denoted as Y^{AR} (yellow corolla) P^{AR} (yellow pollen) and S^{AR} (petal spot).

Considering the genes in pairs the following results are obtained :—

Y^{AR} P^{AR} 6	Y^{AR} p^{AR} 5	y^{AR} P^{AR} 7	y^{AR} p^{AR} 5
Y^{AR} S^{AR} 5	Y^{AR} s^{AR} 6	y^{AR} S^{AR} 7	y^{AR} s^{AR} 5
P^{AR} S^{AR} 7	P^{AR} s^{AR} 6	p^{AR} S^{AR} 5	p^{AR} s^{AR} 5

Although the numbers are small it is evident that the three *Armourianum* genes are *independently inherited*, as is also the case in the analogous genes in *barbadense*, and in the Asiatic group.

Summary.

(1) A first cross between *G. armourianum* and *G. barbadense* segregated sharply in respect of three pairs of characters.

(2) The *G. armourianum* parent thus possessed three genes in a heterozygous state, *viz.*:
Y^{AR}-y^{AR} (yellow-cream corolla).
P^{AR}-p^{AR} (yellow-cream pollen).
S^{AR}-s^{AR} (petal spot-spotless).

(3) The three genes shewed independent inheritance, as in the New World and Asiatic groups of cotton.

References.

Skovsted, A. (1935)—"New interspecific hybrids in the genus *Gossypium* L." *J. Genet.* **30**. 447-463.

DETERIORATION OF STRUCTURES IN SEA WATER.

Omitting decay, the principal cause of damage to timber structures in sea water is the *Teredo* or *Bankia*, commonly known as the ship-worm, and certain allied species. The ravages of these molluscs were evident in the earliest days of ship-building, and they are recorded to have proved disastrous in the fourth voyage of Columbus, whose ships were "pierced with worm-holes like a bee-hive". At the present day, the damage done to timber piling in various parts of the world may be reckoned in millions of pounds. The Romans are stated to have made the discovery of a species of wood which is immune, but their secret is lost, and so far as current knowledge goes, there is no timber which is indubitably free from liability to be attacked. As the result of the experiments carried out, the Committee came to the conclusion that "no process for the preservation of timber was more satisfactory than that of impregnation with creosote" and that "the efficacy of the process depended on the completeness with which the penetration of the creosote into the timber had been effected". (*Nature*, Vol. 138, No. 3482, pp. 148-149, 1936).

OBITUARY.

THE LATE HON. A. E. COLLENS, F.I.C., F.C.S.

WE regret to announce the death, on 13th April, in Antigua of the Hon. Archibald Edgar Collens, F.I.C., F.C.S., who had represented the Leeward Islands Government on the Governing Body of the Imperial College of Tropical Agriculture since 1921. Mr. Collens was employed in various capacities by the Trinidad Government until 1917 when he succeeded Dr. H. A. Tempany as Government Chemist and Superintendent of Agriculture to the Government of the Leeward Islands. With the reorganisation of the Antigua Department of Agriculture in 1930, Mr. Collens relinquished his post as Superintendent of Agriculture but continued as Government Chemist until the end of 1936, when he retired from the service.

During his long official career Mr. Collens had accumulated a fund of much valuable information, especially on West Indian hurricanes on which he was an authority. Endowed with a genial and helpful disposition he will be greatly missed by his many friends and colleagues in the West Indies.

MR. ERIC MACFADYEN.

As we go to press news has been received that Mr. Eric Macfadyen has been appointed Chairman of the Governing Body of the Imperial College of Tropical Agriculture in succession to the late Sir James Currie.

Born in 1879, Mr. Macfadyen was educated at Clifton College and Oxford University where he was President of the Union. In 1902 he entered the Malay Civil Service in which he remained until 1906 when he took up rubber planting. Whilst in Malaya he became Chairman of the Planters' Association and a Member of the Federal Council of the Federated Malay States. In 1917 he returned to England where he joined the Royal Garrison Artillery as a lieutenant and in 1918 served in France. Mr. Macfayden is a Director of Harrison & Crosfield, Ltd. In 1927 he was Chairman of the Rubber Growers' Association and in 1930 President of the Institution of the Rubber Industry. He was elected a member of the Governing Body of the College in November 1928 and has been a particularly active member of its Finance Committee.

INTERNATIONAL GRASSLAND CONGRESS, 1937.

THE Fourth International Grassland Congress is to be held in Great Britain in July 1937 under the Presidency of Professor R. G. Stapledon, C.B.E., M.A., Director of the Welsh Plant Breeding Station, and of the Imperial Bureau of Plant Genetics: Herbage Plants, Aberystwyth, Wales. The Congress is to be held in collaboration with Der Vereinigung Internationaler Grunlandkongress (the International Grassland Congress Association), which has its central office in Leipzig, Germany (Secy., Dr. Richard Geith).

Specialists from the British Dominions and Colonies, the United States of America, and numerous other countries outside Europe are being invited to take this opportunity of meeting prominent British and European investigators.

The paper-reading sessions will be held in Aberystwyth, on July 15 to 18, 1937. Intending participants will be invited to join in a tour of centres of grassland interest both before and after these sessions.

The paper-reading sessions will be divided into three plenary and two sectionalised sessions. The sectionalised sessions will consider different aspects of the grassland problem, including ecology, pasture and range management, seeds mixtures, plant breeding, genetics, and seed production, manures and fertilisers, nutritive value of pastures, fodder conservation, and grassland economics.

Particulars regarding the acceptance of papers and dates for receipt of abstracts and paper manuscripts may be had from the Joint Secretaries, Agricultural Buildings, Aberystwyth, Great Britain, to whom requests for the preliminary programme and application form for membership and all other correspondence regarding the Congress should be addressed.

OFFICIAL CORONATION PROGRAMME.

The Official Souvenir Programme of the Coronation of King George VI and Queen Elizabeth has just been issued by the King George's Jubilee Trust. It is a complete and authoritive guide to the Coronation.

The Programme is a production of distinction. The embossed cover with a protective transparent wrapper bears the Royal Coat of Arms in full colours and gold, and the arms and crests of every part of the world dwelling under the British flag. John Masefield, the Poet Laureate, contributes "A Prayer for the King's Reign", and John Drinkwater an article on "The King's Majesty". It also includes special photographs of The Royal Family, a short illustrated biography of the King, a description of the Coronation procession, and the full text of the Coronation Service. It is available at the standard price of 2*s*.

The Soils Sections of the American Society of Agronomy and of the American Soil Survey Association have recently been merged to form the Soil Science Society of America, with the object of fostering the study of all branches of soil science. Annual meetings are to be held, and the papers presented are to be published in a volume of Proceedings, which will supersede the annual Bulletin of the American Soil Survey Association. The first president of the new Soil Science Society is Dr. R. Bradfield, Ohio State University.

SUGAR NOTES.

Compiled by the College Department of Sugar Technology.

Comparative Performance of Alcohol and Kerosene as Fuels with or without Pre-heating, using a Fordson Tractor.—*By A. B. Catambay and E. C. Nera.*

Without pre-heating the consumption of kerosene was 7.94±0.061 litres an hour or 55.33±0.539 litres per hectare; and of alcohol, 8.84±0.098 litres an hour or 64.29±0.899 litres per hectare. This result may be expected, because to produce the same power more alcohol is needed than kerosene, the kerosene having a higher heating value than alcohol. By volume, without pre-heating, it took 1.7 times as much alcohol as kerosene to plough one hectare of land. With pre-heating the amount of fuel to plough one hectare of land with kerosene was 7.32±0.158 litres an hour or 52.26±0.799 litres; with alcohol, 8.14±0.089 litres an hour or 59.56±0.429 litres. From these figures, again it is obvious that there was less fuel consumption when kerosene was used. With pre-heating, it took 1.12 times as much alcohol as kerosene by volume to plough the same area.—(*Int. Sugar Jr.* Vol. XXXIX. No. 457, p. 34, 1937.)

* * *

A Machine for Testing the Rind Hardness of Canes.—*R. W. Mungomery.*

This machine is modelled on one constructed by Dr. H. L. Lyon of the Hawaiian Sugar Planters' Association, Hawaii, and in use by the entomologists of that Station. Briefly it consists essentially of a solid brass base, about 9½ ins. diameter, into which are screwed two upright steel columns about ⅝ in. diameter and 17 ins. high. Attached to the upper part of these columns is an adjustable bridge (the position of which is variable according to the thickness of the cane to be tested) which carries the piercing mechanism, and the indicator hand and scale.

Lower down, these columns act as guides for another movable bridge which is actuated by an operating wheel into which is screwed a ¼ in. pitch square thread, allowing the lower bridge to be raised or lowered as requested. On this lower bridge are fixed two opposing pieces of metal, which have V-pieces cut out of them, providing rigid support for the portion of cane to be tested. The needle which pierces the rind of the cane is of the same diameter throughout its entire length, namely 1-25 in. and has a square blunt end.

Operation: The cane to be tested is placed on the lower bridge, and the wheel turned round steadily by hand at approximately the same speed throughout. This has the effect of raising the cane at a uniform rate towards the needle. When the cane first makes contact with the blunt needle, it is not pierced, but is pushed upwards against a spring which is brought into tension. At the same time, the upper portion of the rod which holds the needle operates the indicator arm. This arm is screwed just sufficiently tight to prevent any loose movement, yet not tight enough to exert any undue pressure against the spring when the rod starts the indicator arm moving. A point is ultimately reached when the tension on the spring is sufficient to make the needle puncture the rind. When this happens, the needle suddenly punctures the cane to a distance of ¼ in., leaving the indicator arm free and registering on the scale the tension exerted.

As the rind hardness of any one variety varies considerably in different sticks and in different parts throughout the same stick, a number of sticks are tested and the readings recorded. The requisite number of readings may vary from 250 to 500 and from these, the average tension can be determined.

It is usual to test the rind hardness of a borer-susceptible and a borer-resistant variety, and accept these as standards for comparison. When testing a new cane, one or more of these standard varieties must be grown with it under the same set of conditions; and, by taking tests with the machine on the new variety, in comparison with the standard varieties, it is possible to forecast fairly accurately the new variety's reaction to borer attack.—(*Int. Sugar Jr.*, Vol. XXXIX, No. 457, p. 22, 1937.)

* * *

Nature of Sucrose Caramel. *By G. von Elbe.*

When sucrose has been heated to constant weight (until there has been a loss of 12 per cent. or more), the formation of caramel begins at 140°C. after several hours. It proceeds faster the higher the temperature, but the caramel always has the same composition. The final result is the same whether the sugar is heated in a vacuum or in the open air.

The non-volatile residue consists of a coloured humin substance and two colourless amorphous substances which in the free condition easily decompose with formation of humin, and certain volatile products. In proportion as the formation of humin substance proceeds during the caramelization process, the uncoloured products become more resistant to heat and are less readily soluble in organic solvents.—(*Inter. Sugar Journal*, Vol. XXXVIII, No. 453, p. 352, 1936.)

ERRATA.

West Indian Notes.

Page 120 *Line* 15 *for* examination laid down *read* examination of the experiments laid down.

,, ,, *Line* 35 *for* they are curled inwards *read* they are not so curled inwards.

,, ,, Col. 2 *Line* 9 *for* tree. Significantly *read* tree: significantly.

,, ,, ,, *Line* 13 *for* bisuplhide *read* bisulphide.

,, ,, ,, *Line* 17 *for* &c.). On *read* &c.): on.

CHEMICAL NOTES.

Compiled by the College Department of Chemistry and Soil Science.

Containers used in Tanning.

In the early days of leather manufacture, the chemicals used in tanning were very restricted, namely, lime, bran, dung, vegetable tannins, natural dyewoods, berries, and greases. Under these conditions the problems of the materials of construction were comparatively simple. Pits were made of brick, cement or wood; drums and paddles were wooden. The chief metal to avoid was iron, since, with vegetable tannins, iron readily gives intensely coloured blue or green compounds. It is said that one part of iron in a million parts of tan liquor causes an alteration in the colour which can be detected. Hence iron roofs were avoided and wooden construction employed where possible. Nails, pipes and certain implements were made of copper. When iron bolts were used in the construction of drums, their heads were covered with brass or bronze. To-day the problem is complicated by the wider range of acidity encountered in tanning processes.

Concrete is often used in the construction of pits for the alkaline liming process, the acid deliming and the vegetable tanning processes. Since acid proof concrete is unknown, the use of protective coatings has been recommended, such as paints based on chlorinated rubber and difficult to saponify, drying or semi-drying oils, and asphaltic bitumen. Wood is the material most used for constructional purposes for pits, paddles, drums, pipes, leaches, floors, &c. The kinds used include pitch pine and red deal. No doubt its cheapness is a great consideration where large numbers of vessels are necessary.

A striking feature of the leather industry is that vessels are seldom made of metals except in special cases as, for example, in vacuum tanning, where strength and air tightness are essential. One reason is no doubt the absence of a sufficiently resistant metal. In the U.S.A., the virtues of Monel metal have been recognised, and it has been introduced for lining pickling drums. The lining reduces friction and hence the skins are less damaged; cleansing is facilitated and heating is diminished, avoiding the need to stop the drum for cooling purposes. It has also been used for hoops and lugs for drums and nails for fastening leather to the straining boards. Stainless steel is resistant to many tan liquors free from sulphites. "Staybrite" steel has been found to be perfectly resistant to vegetable tannins. These metals seem to have a future in the leather industry. Aluminium and "Duralumin" have found considerable employment in the construction of plant for the manufacture of gloving leather from kid and goat skin by treatment with aluminium salts. Anodised "Birmabright" (an aluminium alloy), containing 3.5 per cent. magnesium and 0.5 per cent. manganese, does not contaminate tan liquors though it suffers local corrosion.—(*Industrial Chemist*, Vol. XII, No. 143, pp. 546-7, 1936.)

Cacao Fermentation.

In a recent issue of the *Bulletin of the Imperial Institute* (34, No. 3, 1936), Mr. A. W. Knapp, chief chemist to Cadbury Bros., Ltd., concludes a series of articles on "Scientific Aspects of Cacao Fermentation." He deals with the production of acetic acid during fermentation; the effect of ripeness on the process; improved methods of fermentation; processes which have been suggested for bringing about the desired results without fermenting the beans; combined fermentation and heat treatment; and aroma. He sums up in these words: "We have seen that scientists have made valuable contributions to our knowledge of fermentation, but that no theory of the production of the desirable bean is sufficiently complete to enable us to state an alternative to, or improvement on, the traditional methods. In tracing out how the natural processes give us the desirable qualities, many things have been made clear, but the production of the substances which, on roasting, give the characteristic odour and flavour remains obscure".—(*Food*, 1936, p. 59.)

* * *

Translocation of Phosphorus in Plants.

In a letter to *Nature*, No. 3508, Vol. 139, 1937, p. 149, Professor G. Hevesy, K. Linderstrom-Lang and C. Olsen have described experiments which indicate the great mobility of phosphorus within the plant. By growing sunflower seedlings in nutrient solutions containing radio-active phosphorus (which is used as a 'label' for tracking the movement of phosphorus atoms), these investigators have demonstrated a considerable migration of phosphorus from the lower to the upper levels during growth. The bulk of the phosphorus occurs in inorganic combination as phosphate, and probably moves freely within the plant. None of it escapes when cut leaves are placed in a nutrient solution. Germinating maize and pea seeds absorb labelled (radio-active) phosphorus in the germ but not in the endosperm, showing that there is no phosphorus exchange between the two.

* * *

Synthetic Rubber in Germany.

It is reported by the American Consulate General, Frankfort on Main, that preparations are being pushed intensively to create a huge German synthetic rubber industry based on the process of the I.G. Farbenindustrie, whose product "Buna" has been acclaimed as an unqualified technical success and a commercial possibility under a government-controlled economic system. The present production of "Buna", which is said to be "on a large commercial scale", is to be increased several times within a short period in connection with the four-year plan of economic self-sufficiency.—(*Industrial and Engineering Chemistry, News Edition*, Vol. 15, No. 1, p. 12, 1937.)

TREND OF THE MARKETS.

[The notes below are based principally upon running charts of the prices of the basic grades and upon general statistical information gleaned from contemporary publications and cablegrams and are intended to be a record of movements. An attempt is made, where possible, to indicate the market outlook at the time of going to press, but no responsibility for the accuracy and subsequent truth of such observations is assumed. Unless otherwise stated the prices quoted are spot, London.]

SUGAR.—Prices on the Home Markets have ranged as follows (c.i.f. per cwt.)

	Foreign.		*Preferential.*	
	s.	*d.*	*s.*	*d.*
25th February	6	4½	10	0
4th March	6	6	10	2¼
11th March	6	9	10	6
18th March	6	9	10	5¼
24th March	6	4½	10	3
31st March	6	9	10	5¼
7th April	6	8¼	10	5¼
14th April	6	4½	10	1½
(16*th April*, 1936)	5	0	8	9

After ruling firm and very active a quieter tone has prevailed due to a bout of profit taking and some hedge selling. The general undertone, however, remains very steady. With regard to the International Sugar Conference Messrs. C. Czarnikow, Ltd. in their weekly market report for 24th March write " The difficulties facing the Conference have been too well known to permit of any unqualified optimism, and it can hardly be said that present values discount a successful issue for, despite the improvement, prices have still some way to go before reaching the economic level aimed at by the sponsors of the Convention. Even in the event of an agreement being arrived at, however, the question of the ultimate sugar price basis will be determined by the degree of equilibrium attained. Nevertheless, the establishment of some sort of assurance that output will in future be regulated to conform more closely with actual world requirements, without the danger of a repetition of stock accumulations, would restore more lasting confidence throughout the trade, and result in a further considerable hardening of prices ".

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COCOA.—During the Easter holidays the cocoa market advanced 25 to 29 points in the New York Terminal, with the result that the market in other consuming centres responded likewise. This terminal market, however, seems to be ruled so much by the speculative element at this time that it is really difficult to say from day to day how prices may go, and although the higher grades are not influenced, Accra comes under the spell. Later advices report a weaker market for this grade and new crop is offered at 45*s.* whilst locally $14.60 is paid for Plantation Cocoa. —(*By Courtesy of The Cocoa Planters' Association of Trinidad, Ltd.*)

* * *

COPRA.—This has continued steady and West Indian is quoted slightly higher at £20 17*s.* 6*d.* c.i.f. London.

RUBBER.—Quotations for plantation sheet have ranged as follows :—

	Pence per lb.
24th February	.... 10 5/8
3rd March	.... 10 13/16
10th March	.... 11 7/16
17th March	.... 12 3/8
24th March	.... 12 7/16
31st March	.... 13 3/8
7th April	.... 12 1/8
14th April	.... 11 1/8
(15*th April*, 1936)	.... 7 9/16

Prices have recorded sharp advances in a strong market. This movement has been due partly to more active buying by genuine consumers and partly to the action of speculators who have been encouraged by the heavy decline in the United Kingdom stocks and by the strength of commodities in general. The International Regulation Committee fixed the quota for the second half of the year at 90 per cent., an increase of ten per cent. over the quota fixed for the second quarter. According to the *American Questionnaire* American consumption for February was 50,282 tons which is a very satisfactory figure.

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COTTON.—The following are the official spot prices in pence per lb. of the Liverpool Cotton Association.

	American Mid.	*Egyptian F.G.F. Sakel.*
26th February	7.41	10.21
5th March	7.70	10.77
12th March	7.94	11.18
19th March	7.88	12.40
26th March	7.95	12.68
2nd April	7.97	12.76
9th April	7.87	—
16th April	7.47	—
(17*th April*, 1936)	6.58	9.14

There have been sharp advances in American cotton prices, new records having been established in Liverpool and New York. The rise has been due to heavy trade and speculative buying. There has also been a striking advance in quotations for Egyptian qualities which is said to be due to reports of a shortage of supplies of the finer grades of Egyptian cotton. No business is reported in West Indian Sea Island.

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BANANAS.—According to the *West India Committee Circular* for 25th March there has only been a fair demand and prices are unchanged at £17 5*s.* per ton delivered London and £17 nearest station Provinces. Brazilians continue to be quoted at £14 delivered London and £15 delivered Provinces.